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PLANT HORMONES AND THEIR PRACTICAL IMPORTANCE IN HORTICULTURE

By

H. L. PEARSE, Ph.D., A.R.C.S., D.I.C.,

The Research Institute of Plant Physiology, Imperial College of Science and Technology, and The East Malling Research Station

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PLANT HORMONES AND THEIR PRACTICAL IMPORTANCE IN HORTICULTURE

CONTENTS

PAGE

FOREWORD 7

INTRODUCTION 9

THE USE OF PLANT HORMONES IN VEGETATIVE PROPAGATION 11

I. FACTORS INFLUENCING ROOT FORMATION IN CUTTINGS 11

1. Variation of species in ease of propagation 11

2. The source of the cutting and type of material 11

A. Position of basal cut 12

B. Presence of leaves and buds 12

C. Etiolation 13

3. Factors influencing root formation during the rooting period 13

A. Water supply and aeration 13

B. Temperature and light intensity 14

4. The origin of roots in cuttings and internal factors leading to their formation 14

A. Root origin 14

B. The carbohydrate/nitrogen ratio 15

5. Early attempts to influence rooting by introducing foreign substances .. 15

A. Sugar 15

B. Nitrates 15

C. Other empirical chemical treatments 15

(*a*) Acetic acid 15

(*b*) Potassium permanganate 15

(*c*) Other substances 16

II. ROOT FORMATION CONTROLLED BY SPECIAL SUBSTANCES 16

III. THE PRACTICAL USE OF SYNTHETIC PHYTOHORMONES IN PLANT PROPAGATION 19

1. Brief review of literature 19

Cooper 19

Zimmerman and co-workers 20

PAGE

Hitchcock and Zimmerman 21
Tincker 22
Van der Lek and Krijthe 23
Pearse and Garner 23
Hubert and Beke 23
Scholz 24
Gillett and Jackson 24
Grace 24
Gočolasvili and Maximov 24
Komissarov 24
Brase 24
Biale and Halma 24
Stuart and Marth 25
Oliver 25
Evenari and Konis 25
Skinner 25
Wóycicki 25
Tubbs 25
Stoutemyer 25
Longley 25
Chadwick and Kiplinger 26
DeFrance 26
Angelo 26
Johnston 26
Kirkpatrick 26
Hubert, Rappaport and Beke 27
Warner and Went 28
Bailey 28
Baptist 28

2. Practical methods for the propagator 28
A. Substances to use 28
B. Method 28
C. Preparation of the solutions 28
D. Preparation of the cuttings 29
E. Treatment of the cuttings 29
F. Important details 29
G. Care of the cuttings during the rooting period 29
H. Difficult species 30
I. Subsequent growth 30
J. Testing the activity of solutions used 30
K. The dust method 30

PAGE

IV. THE MECHANISM OF INDUCED ROOT-FORMATION 31

1. The action of plant hormones in controlling root formation 31
2. Other substances aiding root-formation 32
3. Substances increasing the efficiency of the hormone treatment 33
   - A. Vitamin B_1 33
   - B. Carbohydrates 33
   - C. Potassium permanganate 33
   - D. Amino-acids and Bios 33
   - E. Theelin 33
   - F. Mixtures of hormones 33
4. The correlation between root- and shoot-formation 34
5. Failure to form roots after hormone treatment 34
6. Root origin and metabolic activity in response to treatment with synthetic plant hormones 35

OTHER EFFECTS OF HORTICULTURAL IMPORTANCE 37

1. On germination of old or damaged seed 37
2. On plant growth generally 37
   - A. Following seed treatment 37
   - B. Following treatment of intact plants or their culture medium .. 38
   - C. Following treatment of culture medium of intact plants with vitamin B_1 40
3. On parthenocarpic development 40
4. On retardation of fruit buds 41
5. On storage of fruit 41
6. On framework control in fruit trees 41
7. On rate of rooting in transplanted trees 42

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES 43

ACKNOWLEDGEMENTS 77

REFERENCES 78

FOREWORD

By Professor F. G. Gregory, Professor of Plant Physiology, Imperial College of Science and Technology, London.

As compared with the long history of established horticultural practices the science of plant physiology must be accounted a very recent innovation. For this reason, perhaps, in the past the scientist has, by his analysis, achieved merely a more precise statement of problems long known to practice. The actual causative agencies controlling the processes of development in plants were, until recently, a matter of speculation only. That special materials are concerned had indeed been clearly foreseen by Sachs in 1865*, and from this time onwards evidence pointing to the soundness of Sachs' intuition has slowly accumulated through the pioneer work of investigators of many nationalities. It has been one of the triumphs of plant physiology recently achieved that some of these substances have been at last isolated and their chemical nature determined. Equally remarkable has been the synthesis of pure chemical substances which in their action can replace the naturally occurring hormones.

During the last ten years, since F. W. Went, by his brilliant researches, opened this new chapter, a vast body of experimental data has accumulated. The scientific implications of these experimental results are not yet in any sense clear, but the immediate practical applications in some respects are so promising that the time has arrived to solicit the attention of the horticulturist.

It is desirable in a new and rapidly expanding field of investigation that the presentation of the results obtained should be left in the hands of those actively engaged in the research, for otherwise the difficulties in experimentation are not properly assessed, nor is the balanced judgment required in evaluating the experimental results forthcoming. In these respects Dr. Pearse is well qualified for the task he has undertaken. No better guarantee for Dr. Pearse's acquaintance with horticultural problems could be given than merely to state that he has spent the last four years engaged in plant physiological research work at East Malling Research Station.

This bulletin does not aim at presenting a full account of recent developments in plant hormone research and indeed the purely scientific aspects have been dealt with in numerous accessible publications, but the practical applications here have been kept steadily in view so that the interest of those likely to benefit from these recent advances is primarily considered. Nevertheless this bulletin will undoubtedly and deservedly find readers in the narrower scientific field, and these should, as does the present writer, feel indebted to the author for providing a lucid account of the practical possibilities and for drawing their attention to problems for further research.

* Wirkung des Lichtes auf die Blütenbildung unter Vermittlung der Laubblätter. Bot. Ztg., 23 : 117-21, 125-31, 133-9.

INTRODUCTION

It has now been established by plant physiologists that certain organic substances which can be prepared synthetically in the laboratory are extremely active in promoting root formation when applied to intact plants or plant parts. The history of the investigations which led up to the discovery of these substances forms a fascinating chapter in botanical research, and has been well told by such recognized experts in this field as Boysen Jensen (1936) and Went and Thimann (1937). An excellent review is also given in a little book by Schlenker (1937). The academic botanist is mainly interested in the question "How does the normal plant grow", whereas to the horticulturist the supreme question is " How can the growth of plants be improved by human intervention ". While the subject of growth controlling substances was still in the stage of examining the behaviour of substances in the normal plant it was of little but academic interest, and therefore had but slight appeal to the practical man. It has recently been found possible, however, to prepare synthetically in the chemical laboratory substances having similar properties to those produced by the plant itself. Since this achievement a very lively interest has been aroused in the effects on the plant of applying these substances. While such experiments may be justly criticized by the plant physiologist as throwing little light on the mechanism of the normal behaviour of substances in the plant, they have undoubtedly produced results of immediate practical importance. Their use in promoting root formation has found immediate practical application, and already there are numerous root-forming preparations on the market based on this work for promoting root formation in cuttings. The Imperial Bureau is continually receiving such queries as "What root-forming substances are available?" and "How can I use them?" and the purpose of this memorandum is, therefore, to record the available information in a readily accessible form to serve as a guide to those interested in the practical use of these substances in propagation.

Anyone who has had practical experience in propagation will realize that after treatment the cuttings need the same careful handling that is normally given, and that many factors influence the response. The first part of this memorandum is therefore devoted to examining the factors which influence root formation, leading up to the discovery of special substances, and finally the methods and factors influencing root formation after treatment with synthetic root-forming substances are discussed.

THE USE OF PLANT HORMONES IN VEGETATIVE PROPAGATION

I. FACTORS INFLUENCING ROOT FORMATION IN CUTTINGS

The vegetative propagation of plants by means of cuttings has been a common practice for centuries. The ease with which different varieties of plants can be multiplied by this method varies widely, so that with difficult subjects other more elaborate methods are often resorted to. A cutting may consist of any part of a plant removed from the parent and thus leaves, stems, roots or tubers may be used ; of these the method of stem cuttings has by far the widest application, and this review is confined almost exclusively to consideration of this type of cutting. Bayley Balfour (1913) believed that all plants can be propagated vegetatively by cuttings provided conditions of water supply, temperature and aeration are adequate. Some plants, for instance blackcurrant and many species of willow, will root very easily from either softwood or hardwood stem cuttings and in these cases no particular care is needed either in the selection of the material for the cuttings or in their treatment during the rooting period. Unfortunately many of the most valuable species horticulturally do not root so easily.

1. Variation of species in ease of propagation

Different species and even varieties of plants vary greatly in the ease with which they can be rooted from cuttings. Many plants can be rooted very readily from either stem, leaf or root cuttings, e.g. many species of *Salix*, *Ribes*, while certain species of *Acanthus* will root even from a portion of an internode, both shoot and root buds being produced as an entirely new formation from the callus.

In some species particular types of cutting will root readily while others are difficult, e.g. *Clematis*, in which internodal cuttings root readily while nodal cuttings rarely form roots.

Other species require special treatment. The *Coniferae*, for example, have resin ducts which exude and thus seal the ends of the cuttings rendering water absorption difficult. If the cut ends are first soaked in nearly boiling water the cuttings will then root much more readily. These few remarks will suffice to indicate the great variability of different species with respect to the ease with which they can be propagated by cuttings. The Plant Hormone Committee of Kew (Metcalf 1938) has recently issued a list of plants which are considered very difficult to propagate.

2. The source of the cutting and type of material

The source of the cutting is a factor of major importance for successful propagation. Thus Knight (1926), who carried out many experiments with cuttings of deciduous fruit trees, pointed out that it is a matter of simple observation to select several different types of shoot at the same time on any one tree. Thus in June there are leader shoots still in active growth which are not lignified to any great extent and have a high water content, lateral shoots in active growth but less sappy, as well as some lateral shoots which may have ceased active growth and become partially lignified. Knight therefore selected different types of shoots for cuttings and divided them into three classes as follows :—

Leader tips in active growth
Laterals in active growth
Laterals with the terminal bud formed.

He found that the partially lignified type of cutting which had ceased growth was much superior to actively growing shoots and tentatively suggested that this was probably due to a higher carbohydrate content in such cuttings. In support of this view he noted that cuttings from potted plants, in which root growth is restricted, often root readily.

Graham and Stewart (1931) and Graham (1934 and 1936) have also shown that the time of year at which cuttings are taken is an important factor, various plants having different optimal periods during which cuttings taken from them are more likely to root successfully, presumably because internal conditions in the material thus selected are then favourable for regeneration.

A. *Position of basal cut*

In preparing stem cuttings the usual practice is to make the cut at a node. While there is no clear reason for this procedure it is usually suggested that greater amounts of carbohydrate are stored at the nodes, and therefore quicker regeneration of tissue occurs and root formation is more rapid. Whether more reserves are in fact stored at the node is questionable. Laurie and Chadwick (1931) made extensive tests to discover the best position for the cut, and out of eighty-six plants tested cuttings of five rooted best when the cut was made above the node, seventeen when the cut was made at the node in the usual manner, forty-one when the cut was made a short distance below the node and twenty-three gave equally good results in at least two of the three regions of cutting. They concluded that the basal cut made at the node in the usual way is not the optimal position for the cut with many of the common shrubs, and that while with some plants it is important that a certain type of cut be made, with many the position of the basal cut can vary from the node to half an inch above or below without influencing to any great extent the rooting ability of the cutting.

B. *Presence of leaves and buds*

Another question which the propagator must decide in preparing his cuttings is whether to remove any of the leaves. Bayley Balfour (1913) while regarding the matter as of little moment in many cases, favoured the retention of all the leaves because he considered that the cutting is thus spared the necessity to heal the wounds caused by leaf removal ; the lower leaves which are sunk in the rooting medium may form roots like the stem and thereby aid water absorption while the additional leaves will aid in the production of food for the cutting.

Later Went (1929) found that in the cuttings of *Acalypha* the presence of buds and leaves promoted the formation of roots. Debudded and defoliated cuttings formed very few roots and under some conditions none. In most cases, therefore, it seems advisable to retain as many leaves as possible on the cuttings.

Van der Lek (1925) found a close relation between the buds and root formation. He states that the removal of buds has a very unfavourable influence on root formation. This was especially true with cuttings of *Ribes nigrum* and *Vitis* and also to a lesser degree with *Salix* and *Populus*. In *Ribes nigrum*, cuttings, from which all buds had been carefully removed, formed roots considerably more slowly and these were much thinner and fewer in number. The influence was noted even when the buds were dormant, but was particularly evident when the buds were sprouting strongly. The influence of the buds persisted also even if their development was prevented by enclosing them in plaster of Paris.

In later experiments (1934) Van der Lek found that with cuttings taken from material which had only just become dormant, the buds did not exercise a stimulating influence on root formation, but on the contrary acted more or less as a check which appeared to be correlated with the fact that the buds were not yet in a condition to sprout. As the buds progressively approach the termination of dormancy the checking effect disappears and is replaced by the stimulating influence.

In this connection also, Molisch (1917) forced shoots of *Salix*, *Populus* and *Viburnum* in September, October and November by warm bath treatments and by smoke and observed that roots developed much faster on these shoots than on untreated shoots. The function of the leaves and buds in promoting root formation will be further discussed later ; here it is sufficient to note that it is usually advantageous to retain as many active buds and leaves as possible on the cuttings.

C. *Etiolation*

Reed (1922) found that cuttings often callussed better when the base of the shoots had been etiolated by keeping in darkness and attributed this to the inhibition of the lignification of the pericycle cells which then more readily became meristematic.

Knight and Witt (1926 and 1927) made some trials with softwood fruit tree cuttings which had been etiolated. They obtained etiolated material of some plum rootstocks in the nursery by layering. The shoots were laid and pegged horizontally during the dormant season and were then covered with a thin layer of soil. When the young shoots appeared through the soil covering, they were etiolated at the base over a length of about two inches, and the young shoots were then detached close to the mother stem. The basal portions of the cuttings were thus etiolated while the apical portion which had developed in light was normal. Control cuttings were taken from the tips of ordinary layer shoots, and were green throughout their length.

The varieties used were the plum rootstocks Pershore, Brompton and Common Mussel and a marked difference was found in favour of the etiolated cuttings. There was also considerable difference in the type of root formation ; a normal plum cutting produces a callus at the basal end and the first roots appear through this callus ; with the etiolated individuals, however, roots were developed at several points on the etiolated portion of the stem and roots were absent from the extreme end, the callus being insignificant or entirely absent.

Knight and Witt considered that there was probably little difference between the food reserves present in the two types of cutting and suggested that other physiological conditions or structural differences were responsible for their different behaviour. They concluded that etiolation either favours the production of root initials, or else modifies the stem in such a manner as to facilitate their development. They also pointed out that not only are roots more easily produced from etiolated than from green stems in the form of cuttings, but the same difference exists also when the stems are still attached to the parent plant, and this fact is employed in the propagation of plums by the method of layering.

3. Factors influencing root formation during the rooting period

Having secured his material the propagator has next to consider what are the most suitable conditions in which to root the cuttings. The main considerations are the maintenance of adequate water supply in the cutting until it is able to absorb for itself, and adequate temperature and aeration at the rooting end of the cutting.

A. *Water supply and aeration*

The main method of influencing the water supply and aeration is by the selection of the rooting medium. Kains(1931) and Swingle, Robinson and May (1924) advocate the use of a fairly coarse sand. Knight (1926) studied the influence of aeration on root and callus formation in hardwood fruit tree cuttings and found that while callus formation occurs more readily in a heavy clay than in sand, actual root formation proceeds more easily in sand, showing incidentally that good callus formation does not necessarily mean good root production.

Zimmerman (1926) found that peat moss or a mixture of sand and peat moss are preferable for some plants, and suggested that there may be some stimulating elements in peat moss which do not occur in sand. He found that species of *Viburnum*, *Ilex* and *Vitis* root very well in this medium.

Laurie (1928) compared rooting in sand and in a mixture of sand and peat. Of ninety-six different varieties of cuttings ninety rooted better in the mixture than in pure sand. He considered the efficiency of the mixture of peat moss and sand to be due to its relatively high water-retaining capacity. Neutralized peat and sand was superior to sand alone so that the favourable action of the peat was not primarily due to its acid reaction. Zimmerman and Hitchcock found with *Ilex opaca* that a mixture of peat moss and sand proved better than peat moss, bank sand, water washed sand or slag as a medium for rooting.

Chadwick (1930) found that cuttings of yew (*Taxus*) rooted differently in various media according to the time of the year at which the cuttings were taken. The poorest rooting occurred

always in a mixture of sand and peat, but while during the months of January and February the highest percentage rooting occurred in sand, during other seasons of the year peat moss proved better than sand. He also observed that the roots formed in a peat medium were less brittle than those formed in sand, which consequently made transplanting easier.

Knight (1926) planted batches of softwood plum cuttings using the varieties Brompton, Pershore, Common Mussel and Damas C at the same time in different media. He used (1) sand, (2) coconut fibre one part and medium loam one part, (3) medium loam three parts and sand two parts, and (4) coconut fibre three parts and sand one part. The superiority of sand except in the case of Brompton was quite distinct. He found that the loss of cuttings occurs chiefly through rotting at the base which is perhaps controlled by the water content of the medium and the degree of hardness of the base of the cutting. Different types of cutting and different varieties are probably able to tolerate different degrees of moisture. Sand is much less apt to become waterlogged, and it is probably due to the better aeration with adequate water supply that more successful results were obtained with sand.

Probably no single rooting medium can be advocated for general use, and the best rooting medium for any particular species of plant can only be determined by trial. For controlled experimental purposes sand is probably the best medium as it can be most readily freed from traces of unknown substances which may affect root formation in media of unknown composition such as peat, and peat moss.

B. *Temperature and light intensity*

Naturally if cuttings are planted in the open, temperature cannot be controlled very rigorously without great expense, but with softwood cuttings the temperature of the rooting medium and the degree of shading are all important factors to consider to obtain the maximum rooting.

4. The origin of roots in cuttings and internal factors leading to their formation

Priestley (1926) pointed out that while external conditions may exert a considerable influence on root development in cuttings, the internal conditions are of major importance. Thus for roots to develop it is necessary that active meristems should be present in the cuttings, and sufficient food must be present to supply the energy for the development of roots by these meristems.

A. *Root origin*

Laurie (1928) considered that root formation generally takes place in adventitious root initials which are found in the meristematic tissue of roots, stems or leaves, and the change which leads to production of these adventitious root initials results from an injury such as severing a cutting from its mother plant.

Hatton, Wormald and Witt (1926) described tumour-like swellings which occurred on several varieties of crab apple. They found a close correlation between the presence of these "burr-knots" or "root-knots" and easy rooting. Cuttings which developed knots easily rooted most readily.

Swingle (1927) examined sections of apple twigs and stated that root primordia arise in branch gaps, leaf trace gaps, the pair of primary rays on each side of each leaf trace after it has entered the stele, and the secondary rays within the leaf trace bundles. No instance was found in which root initials originated from xylem cells or even from phloem cells.

Smith (1925) and Carlson (1929) examined *Coleus* cuttings and found that adventitious roots arise between the bundles in the neighbouring cells of the pericycle.

Zimmerman (1926) pointed out that varieties and species vary considerably in the place of origin of roots in cuttings. Adventitious roots appear with great regularity about certain regions of the stem; in the weeping willow the new roots appear just above the buds, while in *Clematis* the roots form more readily between than at the nodes.

Priestley and Swingle (1929) stated that root formation in dicotyledonous shoots always takes place in the tissues which are closely associated with the vascular supply. Root initials

usually arise in the pericycle from a group of cells that either remain meristematic or become meristematic, and as the stem grows new root initials are formed in association with the vascular cambium.

B. *The carbohydrate/nitrogen ratio*

Many workers have attempted to correlate root formation in cuttings with the balance of carbohydrate to nitrogen in the cutting, Goebel (1903, 1905, and 1908), Reid (1924), Carlson (1929). MacCallum (1905), however, emphasized that nutrient conditions are not the principal factors governing root formation. Kupfer (1907) carried out some very interesting experiments with different varieties of *Commelina* and found that the yellow varieties are very difficult to root while the green ones root easily, but attempts to improve the rooting of the yellow varieties by the addition of sugar or pepsin failed.

Priestley (1926) suggested that " root initials " may arise as the result of the accumulation of food materials where the phloem is severed, and thought that the fact that ringed shoots often root readily might be explained by a piling up of carbohydrate above the ring. Reid (1924) Starring (1924) and Schrader (1925) found that rooting from tomato cuttings was favoured by a high ratio of carbohydrates to nitrogen in the stem.

5. Early attempts to influence rooting by introducing foreign substances

The fact that root formation seemed in some instances to be correlated with the internal food relations of the cuttings led naturally to attempts to alter these relations artificially in a favourable direction for rooting. Thus Reid (1926) grew tomato cuttings that varied in carbohydrate and nitrogen content in nutrient solutions with and without nitrogen and concluded that cuttings with a limited nitrogen supply and a relatively large supply of relatively available carbohydrate appeared to furnish conditions favourable for the growth of roots.

A. *Sugar*

Curtis (1918), experimenting chiefly with *Ligustrum ovalifolium*, found that root growth in immature cuttings was greatly increased by treating the cuttings with cane sugar ; the cuttings absorb the sugar and store it in their stems as starch. Continuous treatment with sugar proved detrimental however, because the sugar solution favoured the growth of bacteria and fungi.

Chadwick (1929) found that sucrose proved beneficial to evergreen cuttings by increasing the percentage of rooting and the length and number of roots, while Laurie (1928) found 2% sugar beneficial in a number of tests.

Knight (1926) found that the treatment of hardwood fruit tree cuttings with sugar produced a marked increase in callus and root formation and that the extent of the stimulation varied with the concentration. The concentration of the sugar before and after treatment remained the same, showing that there was no selective absorption.

B. *Nitrates*

Knight (1926) working with cuttings of several varieties of plum, apple and cherry rootstocks found that treatment of cuttings with potassium nitrate before planting decreased root formation.

C. *Other empirical chemical treatments*

(*a*) Acetic acid

Small (1923) advocated the use of acetic acid as a stimulant for rooting cuttings. Experimenting with a large number of ornamental and greenhouse plants he found acetic acid to be very beneficial. He recommended the use of three teaspoonfuls of vinegar to a gallon of water.

Laurie (1928) also found acetic acid beneficial in a number of tests.

(*b*) Potassium permanganate

Curtis (1918) found that cuttings treated with potassium permanganate for 24 hours, five days or continuously, showed a marked rooting response. He suggested several theories for this

stimulation, e.g., a change in the nature of the food supply of the cutting, an effect on the rest period, a change in the balance of food supply between the tops and the roots in favour of the latter, a disinfectant action or an increase in respiratory activity by catalytically hastening oxidation. He considered that the last theory is the most probable explanation.

Knight (1926), working with cuttings of deciduous fruit trees, found no constant effect similar to that obtained by Curtis by treatment with potassium permanganate.

Chadwick (1929), using evergreen cuttings, found treatment with potassium permanganate to increase both the number and length of roots formed. The treatment consisted of either placing the cuttings in a solution of the substance for a definite number of hours or applying a solution directly to the rooting medium before planting.

Laurie (1928) also found a ·01 % solution of permanganate a useful aid in rooting.

Zschokke and Feurer (1927) treated apple and quince cuttings with hot water, ether and potassium permanganate, but failed to stimulate rooting.

(*c*) Other substances

Arena (1927) found that salts of zinc or boron added to Pfeffer nutrient solution in dilute concentration induced abundant root formation and leaf formation in cuttings of *Alternanthera spatula*. Nitrogen and calcium salts produced similar results in 3, 4 and 5 days. Other tests in which salts of potassium, magnesium, calcium or ammonia were added in like dilution were much slower in response.

Dachnowski (1914) found that tomato cuttings grown in potassium hydroxide n/800 showed greater root development than in water, while no roots were produced on cuttings treated with hydrochloric acid n/800. He found that the addition of salts of sodium, calcium or potassium helped to counteract the injurious effect of hydrochloric acid and increase root production.

Knight (1926), using hardwood cuttings of deciduous fruits, found boric acid ·005 M to inhibit rooting.

Curtis (1918), using mainly cuttings of *Ligustrum* and tomato, found various compounds of manganese, iron and phosphorus often to improve rooting.

Winkler (1927) found various oxidizing agents greatly to stimulate callus and root formation in vine cuttings (*Vitis*). Of these agents used, potassium permanganate showed least stimulation, but even this substance showed marked stimulation as compared with control cuttings.

Other stimulating reagents were manganese sulphate, potassium ferrocyanide and sodium peroxide, and the subsequent shoot growth was also greatly stimulated by these reagents. The stimulation by reagents not liberating oxygen was greatly retarded in the absence of air.

In general the use of these chemicals for root stimulation indicates that a great deal of variability occurs, and while many types are benefited by the treatments, other more difficult subjects do not show any stimulation.

II. ROOT FORMATION CONTROLLED BY SPECIAL SUBSTANCES

Sachs (1880) was the first to point out that the phenomena of root formation in cuttings could be best explained by the assumption of a specific substance formed in the shoots. This substance, normally transported towards the base, caused the appearance of roots in cuttings, as it could not be conveyed farther downwards, and was therefore accumulated at their base.

Van der Lek (1925) showed that root formation in cuttings of *Salix*, *Populus*, *Ribes* and *Vitis* is largely dependent upon the existence of buds, especially of strongly sprouting ones. Roots can be produced by cuttings with all the buds removed, but they are less abundant and smaller than in cuttings with buds present. Van der Lek therefore assumed that one or more hormones are formed in sprouting buds which are transported in a basal direction through the phloem and stimulate root formation. In the case of abundant root formation in cuttings with excised buds, he was able to demonstrate the existence of root germs or initials which are likely to develop without the necessity for the presence of the hormone.

Beijerinck (1886) noted that the presence of leaves stimulates root formation, though he apparently regarded this as mainly due to the nutritional effect, but Went (1929) using *Acalypha* cuttings was able to show that the buds strongly and the leaves less strongly promoted the formation of roots. Debudded and defoliated cuttings formed very few roots, or under some conditions none. If, however, a diffusate from *Papaya* leaves were mixed with agar, and applied to the defoliated or debudded cuttings an increase in the number of roots produced was observed. Still greater increases were later obtained by the application of diastase which was also active after being boiled.

Bouillenne and Went (1933) found that extracts of rice polishings were also active in promoting the formation of roots. The action of the extracts is exerted only at the base of the cutting and inversion with respect to gravity did not alter this polarity ; it was therefore deduced that " the polar localization of new roots is caused by the polar transport " of the hormone. They therefore concluded that root formation is due to a special substance or hormone which they named " rhizocaline " ; the substance itself is not a nutrient, is thermostable and is produced by the leaves in the light. It is also stored up in cotyledons and buds, and its transport is basipetally polar.

Laibach (1934), Laibach, Müller and Schäfer (1934) and Müller (1935) showed that extracts of urine and pollen applied to the internodes of *Coleus* and *Tradescantia* were active in promoting the formation of adventitious roots.

Němec (1930) found that smearing the cut surface of root cuttings of *Cichorium intybus* with a culture of *Bacterium tumefaciens* had a stimulating effect on the production of new roots. The production of a similar root-forming substance by bacteria would explain this result. In a later paper (1934) the same author confirmed the fact that cotyledons and buds store not only food materials but also special root-forming substances. He placed isolated hypocotyls of *Helianthus* or *Lupinus* in aqueous extracts of cotyledons, terminal buds or stems. All these extracts increased the number of roots formed at the base of the hypocotyls.

Molisch (1935) also found that budless internodes of various plants root only weakly or not at all. He concluded that the buds contain a root-forming substance, and also that they prolong the life of the internode.

The discovery that root formation is controlled by special root-forming substances led naturally to the need for a quantitative method of estimation. Went (1934) worked out such a method using etiolated pea shoots. The procedure was as follows :—Seeds of a pure strain of *Pisum sativum* are disinfected with mercuric chloride and then just covered with water and allowed to soak for 4 to 6 hours. They are then planted in well washed sand in seed pans. The pans are then placed in a dark room maintained at high humidity (85 to 90%) ; all further manipulation is carried out in faint red light and at a constant temperature of 25°C.

A week after planting, when the plants are about 10 to 15 cm. high they are cut off at about 1 or 2 mm. above the first node. At the first and second nodes only scales develop, but on the third node the first normal leaf appears. The tip of the shoot is next cut off just under the third node, so that the experimental plant consists of the second and third internode.

The cut shoots are then placed together for about 4 hours with their bases in the water, and and for the following 4 hours this water is replaced by a 0·05% solution of potassium permanganate for disinfection. One c.c. of the solution to be tested is then placed in bottles having a diameter of about 1 cm. The bottles to be used must be cleaned thoroughly, special care being taken to remove all traces of oxidizing agents.

After the 4 hours in the permanganate this is rinsed off the base, and the apical part of the plant is then slit lengthwise down the middle with a razor blade for a distance of about 1 cm.

The apical slit ends are then immersed in the test solutions for about 12 to 15 hours in a dark room with a medium humidity of 60 to 70%, 5 plants being used for each bottle. At the end of this time the immersed ends are rinsed with water, and they are then placed in 5 c.c. of 2% sucrose. The sucrose used must be extracted beforehand with ether or chloroform, for even the purest products contain physiologically active amounts of toxic substances which decrease the activity of the plants considerably. After six days in the sugar solution the plants are transferred to tap water.

For root development after treatment the most favourable conditions are in a dark room

at 25°C. and 60-70% humidity. The first roots develop 4-5 days after treatment, the sooner, the higher the concentration of root-forming substance. The final count is made fourteen days after the treatment with the test solution, as the number of roots does not increase after this time. Went found that there was an approximate linear relation between the concentration of the root-forming substance and the number of roots formed. A few roots were produced on the water-treated control plants which he presumed was due to root-forming substance stored in the scales of the shoots.

For roughly quantitative methods the root-forming solution can be mixed with lanolin and applied on the radial cut surfaces of the apically slit shoots.

Thimann and Went (1934), using the pea root test outlined above investigated the nature of the root-forming hormone. In order to understand their findings it now becomes necessary to digress for a space to consider briefly parallel researches which throw light on the nature of correlation in plants.

Everyone who has tried to grow plants in a window is familiar with the fact that plants grow and curve towards the light ; Darwin as long ago as (1880) in studying this bending response to light in the first leaf (a cylindrical organ called the coleoptile) of a grass, *Phalaris canariensis*, discovered that the light stimulus is perceived only by the region just below the tip. If this tip is removed the coleoptile fails to bend in response to the light stimulus. Following Darwin various workers including Boysen Jensen (1910-11), Paal (1918), Stark (1921), Söding (1925), Seubert (1925) and Went (1928) carried out researches with coleoptiles, using mainly that of the oat, *Avena sativa*. This work finally showed that there is apparently a substance formed in the tip of the coleoptile which diffuses downwards and brings about enlargement of the cells. If the extreme tip of the coleoptile be removed (1-2 mm.), growth stops. If, however, the tip is replaced on the decapitated stump, growth is resumed. The active substance responsible for the cell enlargement in the coleoptile can be extracted from coleoptile tips by placing them on thin sheets of 3% agar. If the agar on which such tips have been standing is cut into small blocks and these blocks are then placed on the stumps of decapitated coleoptiles, growth recommences in the stump.

The actual amount of growth is small but Went (1928) elaborated a technique whereby the small agar blocks are placed in contact with one side only of the coleoptile stump. The active substance then diffuses down this side causing a growth response with the result that the coleoptile bends. Over certain limits the angle of bending is proportional to the amount of substance present in the agar block.

It is clear then that the growth of the coleoptile is regulated by a definite chemical substance. This substance was named auxin, and from analogy with the term hormone, which had been used by the animal physiologists to denote a substance produced by one tissue which is able to influence in some specific way the functional activity of another tissue, it is evidently a plant hormone or phytohormone.

Auxin is apparently widespread throughout the plant kingdom, for using the coleoptile of *Avena* as a test object it has been detected in many dicotyledonous seedlings such as *Lepidium sativum*, *Vicia Faba*, *Raphanus sativus*, etc. Human and animal urine are rich sources of auxin.

Three hormones have now been obtained chemically pure from organic material. In certain fungi it has been possible to extract a substance which Kögl, Haagen Smith and Erxleben (1933) have named hetero-auxin. From urine the same workers have isolated two other hormones to which they have given the names auxin a and b. The empirical formula of hetero-auxin is $C_{10}H_9O_2N$; of auxin a, $C_{18}H_{34}O_5$ and of auxin b, $C_{18}H_{30}O_4$. Heteroauxin is β-indolyl-acetic acid, a compound which had been known chemically long before its potency as a plant hormone was discovered. A more detailed review of chemical relationships will be found in a book by Nicol (1938).

Auxin a and b have not yet been synthesized and they lose their activity after a few months. Auxin a is stable in the presence of acid and is sensitive to alkali, and auxin b is destroyed by both acids and alkalis, while heteroauxin is sensitive to acids and stable in the presence of alkalis. All these compounds are effective in promoting the growth of the coleoptile, heteroauxin being about half as potent as auxins a and b. There is good reason to suppose that these or similar growth hormones occur universally in plants.

To return now to the root-forming substance, Thimann and Went (1934), using the pea root test, found that it was present in a number of pollens and other natural products, and occurs almost always together with auxin (detected by its effect on the *Avena* coleoptile). In some cases there was even a good quantitative parallelism between root-forming and growth-promoting activity; thus an extract of *Rhizopus*, rich in auxin, was also very rich in root-forming hormone. They found that the root-forming substance was extractable by organic solvents only from acid solutions and is therefore an acid. The distribution between different solvents was the same as that of auxin. The activity was readily destroyed by oxidizing agents and followed that of auxin throughout the various stages of purification, even through vacuum distillations. Therefore although it was not proved that the substance was identical with auxin, it is evidently very closely related to it.

Thimann and Koepfli (1935) and Kögl (1935) found later that auxin b, and synthetic β-indolyl-acetic acid were as active in root formation as the purest *Rhizopus* preparation. They considered that this was final proof therefore, that one, at any rate, of the hormones causing root formation is identical with auxin. The evidence against the identity of the root-forming substance with auxin is that the root-forming and growth-promoting activities of various natural preparations are not always quantitatively parallel.

Laibach (1935), Fischnich (1935) and Laibach and Fischnich (1935) observed that roots could be produced on intact plants of *Coleus*, *Vicia Faba* and *Solanum lycopersicum* by dissolving β-indolyl-acetic acid in sheep's wool fat (lanolin) and applying this preparation as a paste to the stem.

The fact that β-indolyl-acetic acid was thus found to be an active root-forming substance, and that, unlike auxins a and b, it is comparatively stable and can easily be synthesized chemically led naturally to investigations of its practical importance to the propagator. Cooper (1935) was the first worker to investigate the practical use of β-indolyl-acetic acid and found that applying a paste of this substance dissolved in lanolin to lemon cuttings greatly stimulated root formations. At the Boyce Thompson Institute in New York investigations had been proceeding for some years on the effect of illuminating gas on the growth of plants, and it had been observed that one of the effects of exposing tomato plants to either ethylene vapour or carbon monoxide gas was to cause the initiation of adventitious roots on the stems of the plants. The similarity of this effect and the production of roots by applications of β-indolyl-acetic acid was realized and therefore, in view of the fact that root-forming properties were evidently not specific to the auxins, Hitchcock (1935) and Zimmerman and Wilcoxon (1935) were encouraged to test many other substances for their root-forming capacity, some closely related to indolyl-acetic acid, and some differing widely in chemical constitution. In this way they discovered several root-forming substances in addition to the auxins and β-indolyl-acetic acid, some of the most active of which were phenyl-acetic acid, phenyl-propionic acid, indolyl-propionic acid, and α and β naphthalene-acetic acids. Their preliminary tests were carried out using chiefly the tomato as the test plant, but they immediately proceeded to test the effectiveness of these substances for rooting cuttings with quite remarkable results in some cases, the number of roots per cutting being greatly increased, and the time taken for root formation to start greatly reduced.

III. THE PRACTICAL USE OF SYNTHETIC PHYTOHORMONES IN PLANT PROPAGATION

1. Brief review of literature

Cooper

Cooper (1935) investigated the practical use of β-indolyl-acetic acid applied by the lanolin method of Laibach. One part of the substance was mixed with 2,000 parts of pure lanolin in which it is soluble, and a small portion of this paste (approximately 10 mg.) was then smeared on to a small area of the cutting near the top which had previously been scraped to remove the epidermis and outer cortical layers.

(*a*) Lemon

Twigs of the mature wood of the current and of the previous year's growth were taken from a Eureka lemon tree on April 30th and were made into cuttings about 5 inches long and with 4 or 5 leaves. The treatment not only caused greatly increased rooting as compared with controls, but accelerated rooting considerably. Apical cuttings of terminal growth formed roots sooner than basal cuttings. The treatment not only caused increased production of roots on cuttings with leaves, but also caused root formation on cuttings without leaves, while on control cuttings without leaves no roots were formed.

(*b*) Lantana

Cuttings were taken on March 10th about 2 inches long and consisting of one internode and one node at the top with two subtending leaves. The treated cuttings produced a much larger number of roots than the untreated cuttings, and, while most of the roots on the untreated cuttings appeared at the base, on the treated cuttings roots were formed all over the internode.

(*c*) Acalypha

Cuttings taken on March 19th without leaves and planted in sand with bottom heat after treatment showed over six times as many roots as control cuttings.

Zimmerman and co-workers

Zimmerman, Crocker and Hitchcock (1933), and Zimmerman and Hitchcock (1933) had demonstrated the effectiveness of carbon monoxide, ethylene, acetylene and propylene in causing root formation on certain plants. Hitchcock (1935) using indolyl-propionic acid, pheny-acrylic acid, and phenyl-propionic acid in addition to indolyl-acetic acid dissolved in water, oil or in lanolin and applied locally to intact plants, caused the formation of adventitious roots, and bending of the leaves and bending of the stems in several varieties of plant. Zimmerman and Wilcoxon (1935) found that the following additional substances were active in root-formation: α-naphthalene-acetic acid, β-naphthalene-acetic acid, acenaphthyl-(5)-acetic acid, indolyl-butyric acid, phenyl-acetic acid, fluorene-acetic acid, anthracene-acetic acid and α-naphthyl-acetonitrile. The following species of plants were used in their experiments :—African Marigold (*Tagetes erecta* L.), tomato (*Lycopersicum esculentum* Mill.), buckwheat (*Fagopyrum esculentum* Moench), sweet pea (*Lathyrus odoratus* L.), Windsor bean (*Vicia faba* L.), sunflower (*Helianthus debilis* Nutt.), Jerusalem artichoke (*Helianthus tuberosus* L.), dahlia (*Dahlia variabilis* Desf.), mimosa (*Mimosa pudica* L.), and (*Chenopodium album* L.).

The compounds, which included also those previously used by Hitchcock, were used as solutions in distilled water or mixed with lanoline. Cuttings were placed in small dishes so that the basal ends were immersed in the solutions. Water solutions were introduced into the stems and petioles of growing plants by means of glass tubes drawn to a capillary at one end. Lanolin preparations were applied locally by rubbing the mixture on stems or leaves with a glass rod. The principal responses shown by treated plants were formation of roots on stems and leaves, swelling and bending of petioles and stems. When applied to stems many of the substances caused the formation of roots on growing plants of tomato, sunflower, marigold, artichoke, buckwheat, dahlia and tobacco. α-naphthalene-acetic acid and indolyl-butyric acid were especially effective for producing roots on stems. If the plants were kept in a humid atmosphere after treatment, the new roots forced their way out through the epidermis. Through comparative tests of root formation on tomato plants Zimmerman and Wilcoxon placed six of the most active compounds in the following order of effectiveness.

(1) α-naphthalene-acetic acid
(2) Indolyl-butyric acid
(3) Indolyl-acetic acid
(4) Indolyl-propionic acid
(5) Phenyl-acetic acid
(6) Fluorene-acetic acid.

Under comparable conditions they reported that similar concentrations of indolyl-acetic acid were not so effective for producing roots as either indolyl-butyric or α-naphthalene-acetic acid. Under favourable conditions 5-10 mg. of indolyl-butyric acid or α-naphthalene-acetic acid per gram of lanolin caused roots to appear through the epidermis on tomato in 6 days, marigold in 5 days, tobacco in 8 days, and artichoke in 6 days after treatment. Water solutions of both indolyl-butyric acid and α-naphthalene-acetic acid were effective for producing roots over a range of 1 to 100 parts per million.

Hitchcock and Zimmerman

Hitchcock and Zimmerman (1936) later investigated the rooting response of cuttings, particularly of woody species, after treatment with various of these substances. The following crystalline acids were used, indolyl-acetic acid, indolyl-butyric acid, indolyl-propionic acid, phenyl-acetic acid and α-naphthalene-acetic acid.

Solutions of each hormone were prepared by first dissolving the crystals of the pure substance in a few drops of 95% ethyl alcohol and then adding the required amount of tap water. The low solubility of these substances in water made such a procedure necessary in order to obtain rapid solution. Dilutions were made from a standard stock solution containing, as a rule, 20 mg. per 100 c.c. water. Fresh stock solutions were made each day. Control tests showed that the small amount of alcohol was without effect on the plant material.

The treatment was as follows :—the basal ends of the cuttings were placed in minimum amounts of the test solution to a depth of about $\frac{1}{2}$ to $\frac{3}{4}$ inch. After remaining in the solution for the required period, usually from 6 to 48 hours, the cuttings were planted in the rooting medium in a greenhouse together with control batches which had remained in tap water for the same period.

The rooting mixture consisted of sand and peat moss 1 1 mixture, and some or all of the leaves were left on the lower part of the cutting. These were then placed in the rooting mixture so that from $\frac{2}{3}$ to $\frac{7}{8}$ of the stem was buried, and the leaves or parts of the leaves lay close to or nearly flat on the surface of the substrate. Cheesecloth was placed over the cuttings for the first 10 days or three weeks and was only removed during periods of continuously cloudy weather. Hitchcock and Zimmerman found that in general hardwood cuttings without leaves responded to treatment much less readily than hardwood cuttings with leaves.

Typical responses were obtained. Thus the most effective treatments for *Ilex opaca* Ait were as follows, using cuttings taken from a six-year-old plant during the last week in December.

Indolyl-acetic acid 40 mg. per 100 c.c. for 6-8 hours.
,, ,, 20 ,, ,, ,, ,, 6-48 ,,
,, ,, 10 ,, ,, ,, ,, 18-54 ,,
,, ,, 4 ,, ,, ,, ,, 54 ,,

α-naphthalene-acetic acid 20 mg. per 100 c.c. for 6 hours.
,, ,, 10 ,, ,, ,, ,, 6-24 ,,
,, ,, 4 ,, ,, ,, ,, 6-24 ,,
,, ,, 2 ,, ,, ,, ,, 24-48 ,,
,, ,, 1 ,, ,, ,, ,, 54-96 ,,

The effectiveness of the treatment was exhibited by much earlier rooting, more roots, a larger root system, growth of roots from stem tissue above the base as well as at the base, and a close relationship between rooting response, concentration of hormone and duration of the period of treatment.

α-naphthalene-acetic acid was effective at slightly lower concentrations than indolyl-acetic acid. Indolyl-propionic acid was much less effective than either indolyl-acetic acid or α-naphthalene-acetic acid. Indolyl-butyric acid was not tested.

Ilex crenata Thunb. responded well. Optimum treatments were indolyl-butyric acid 0·4-2 mg. per 100 c.c. for 16-24 hours and α-naphthalene-acetic acid 2-5 mg. for 16-24 hours.

Pachysandra terminalis Sieb. and Zucc. responded best to treatment with α-naphthalene-acetic acid 2-10 mg. per 100 c.c. for 24 hours.

Hibiscus syriacus L. roots emerged through the bark tissue above the basal cut surface as the result of treating dormant cuttings with solutions of indolyl-butyric acid (0·8-4 mg. per 100 c.c. for 3 days).

Earlier rooting of *Taxus cuspidata* Sieb. and Zucc. cuttings was obtained by treatment with α-naphthalene-acetic acid 4 mg. per 100 c.c. for 24 hours.

The lanolin method was also used. Here the synthetic crystalline compounds were mixed with lanolin in amounts ranging from 0·1 to 100 mg. of the substance to 1 gram of lanolin (0·01-10%). The vessel containing the mixture was immersed in warm water long enough to melt about half of the lanolin and then the preparation was stirred thoroughly with a glass rod, and applied to the basal portion of shoots which were from two to five inches in length. The length of the treated region was from one-half to three quarters of an inch long. Shoots treated in this manner were cut off just below the treated region at a time ranging from several days to several weeks after the preparation had been applied. Most of the cuttings were then planted in a mixture of half peat moss and half sand by volume. Control cuttings were treated in a similar manner with pure lanolin. Treatment of plants growing in the open was made at various times from the spring until the autumn. Plants growing in the greenhouse were treated during the winter as well as at other periods.

With the exception of a few *Pyrus* (apple) cuttings lanolin preparations failed to induce rooting in *Pyrus*, *Prunus* and *Crataegus*, but *Acer palmatum* Thunb. responded consistently to treatment with lanolin preparations. Indolyl-acetic acid was effective in concentrations from 10-50 mg. per gram. When the treatments were successful rooting was earlier, more roots were produced and roots emerged from the stem above the base of the cutting as well as at the base.

Phenyl-acetic acid was much less effective than either indolyl-acetic acid or indolyl-propionic acid. Indolyl-butyric acid and α-naphthalene-acetic acid were not available when the tests were made.

Following these pioneer researches many workers in various parts of the world have investigated the practical use of these substances in rooting cuttings.

Tincker

Tincker (1936 and 1938) has carried out tests at Wisley with many cuttings of many different species of plant.

The methods used by him and the results obtained were as follows :—

(*a*) Lanolin paste method

This method was not very successful ; only with readily rooting species, such as tomato and *Pelargonium*, was increased root formation induced, and some acceleration was also observed with such species as *Buddleia alternifolia*. With difficult plants such as *Acacia* and *Pittosporum* the tests were negative. Tincker also points out the disadvantage from the experimental standpoint of the difficulty in accurately measuring the amount of paste applied.

(*b*) Solution method

Concentrated stock solutions were kept in the dark to prevent decomposition, and dilute solutions were prepared from the stock immediately before use. Other solvents such as acetone, ethylene-glycol-mono-ethyl-ether and ethylene-glycol-mono-methyl-ether were found to be as effective as 95% alcohol. The method of treatment was substantially the same as that of Hitchcock and Zimmerman. Results varied according to whether the plants root easily or not.

Thus in easily rooted plants a higher percentage of the cuttings rooted and more roots developed from each cutting. The response was confined almost entirely to leafy cuttings, leafless cuttings from deciduous shrubs in winter showing little or no response.

In plants moderately difficult to root a higher percentage of the cuttings rooted after treatment in 70 per cent of the species tested.

In plants known to be very difficult to root normally only five species responded to the treatment.

(*c*) *Spraying*

Cuttings already planted in the frames were sprayed at intervals with the solutions. Tests with *Arbutus Unedo* and *Eucalyptus coccifera* were unsuccessful.

(*d*) Immersion of leaves in solution

Using a species known to respond readily Tincker immersed the leaves in a solution of indolyl-acetic acid for 48 hours at a concentration of 1 in 20,000. The method was not satisfactory.

(*e*) Treatment of rooting medium

Watering the rooting medium with the solution gave successful results in some cases, but was found to be a rather wasteful method and for experimental purposes the amount absorbed by the cuttings could not be measured.

Tincker used chiefly phenyl-acetic acid, α-naphthalene-acetic acid, β-indolyl-acetic acid and β-indolyl-butyric acid. Of these all except phenyl-acetic acid were found to be highly active in promoting root-formation.

Van der Lek and Krijthe

Van der Lek and Krijthe (1937) made several tests with indolyl-acetic acid using (*a*) the lanolin paste method (*b*) the solution method and (*c*) continuous absorption of solutions from little cups attached to the base of the cutting. With woody cuttings of apple, myrobolan and *Wisteria*, methods *a* and *c* gave quite negative results. Van der Lek and Krijthe stressed the importance of the type of cutting and its state of development in governing the response to treatment.

They found the solution method of Hitchcock and Zimmerman to be most satisfactory and short periods of immersion up to 24 hours more effective than longer exposures. They classified the results of treatment under two headings :—

(1) An increase and acceleration of the type of root-formation which occurs without treatment.

(2) The stimulation of root formation on other portions of the cutting than is usually the case, i.e., internodal root-formation in species which normally root only at the nodes, and vice versa.

When the concentration of solution used was too high damage and abnormal growth occurred.

Pearse and Garner

Pearse and Garner (1937) and Pearse (1939) using α-naphthalene-acetic acid and indolyl-butyric acid treated several varieties of softwood fruit tree cuttings by the solution method. Most of the varieties they used were either moderately difficult or very difficult to root. Many of these varieties rooted well after treatment ; the state of the cutting, degree of lignification, whether growing or non-growing, and condition of the parent material were found to be important factors in controlling root-formation after treatment.

Hubert and Beke

Hubert and Beke (1938) treated cuttings of a great number of species with solutions of indolyl-acetic acid. They used concentrations from 0-100 mg. per litre, with immersion times from 4-24 hours. The cuttings were planted in pure quartz sand.

Control plants were placed in tap water, but they found it advisable to use a second series, which was planted immediately, as the treatment with tap water was advantageous to some species and injurious to others.

Scholz

Scholz (1937) treated cuttings of over 100 plant species with solutions of β-indolyl-acetic acid ranging from 0·001 to 0·02% for 24 hours. Twenty-three varieties gave a hundred per cent rooting, thirty-four gave distinctly better results after treatment, eight slightly better, thirty-one did not root either with or without treatment, and in four the treatment was detrimental. With optimum concentration the treatment increased both the number and length of roots per cutting. The state of maturity of the cuttings treated affected the response.

Gillett and Jackson

Gillett and Jackson (1937) found treatment with a solution of indolyl-acetic acid at a concentration of 1 part in 10,000 for 18 hours to increase the percentage rooting in cuttings of *Coffea arabica*. The cuttings were planted in a mixture of peat moss and sand, and watering with dilute Cheshunt compound proved beneficial in preventing bacterial and fungal infection of the cuttings.

Grace

Grace (1937) incorporated synthetic plant hormones in a dust, using talc or a mercurial dust disinfectant. The hormones were thoroughly mixed with the carrier by shaking. In treating cuttings with the preparations, the lower ends of the cuttings, in bunches up to 50, were dipped in the dust, the excess removed by shaking, and the cuttings were then planted immediately. 1000 parts of hormone per million parts of talc dust, using either β-indolyl-acetic acid, β-indolyl-butyric acid or α-naphthalene-acetic acid, were effective with several species of cuttings.

Gočolašvili and Maximov

Gocolašvili and Maximov (1937) treated cuttings from the trifoliate orange (*Poncirus trifoliata*) and from the Unshiu tangerine (*Citrus Unshiu*) with indolyl-acetic acid by the solution method. The number of cuttings rooting was greatly increased by the treatment. Cuttings taken in spring responded more readily to treatment than those taken in winter.

Komissarov

Komissarov (1938) experimented with β-indolyl-acetic acid, phenyl-acetic acid, phenyl-propionic acid and α-naphthalene-acetic acid. The solution method was used and concentrations varied from 0·001% to 0·020% with immersion times of from 6 to 72 hours. Summer cuttings were planted in a sandy seed bed and winter cuttings in earth. Indolyl-acetic acid treatment gave a greater percentage of rooted cuttings, a larger root system and earlier rooting when the dosage was optimal. Phenyl-acetic and phenyl-propionic acid were much less effective and summer and winter cuttings from *Populus alba* and *Ribes rubrum* were the only ones that responded readily. α-naphthalene-acetic acid was very effective with several species. The effectiveness of the treatments was greatly influenced by the age of the mother plant and the degree of lignification of the cuttings.

Brase

Brase (1938) experimented with softwood cuttings of deciduous fruits using indolyl-butyric acid and indolyl-acetic acid applied by the lanolin paste method and by the solution method. Cherry and pear cuttings responded well when the cuttings were taken before the shoot growth had become completely woody, but with several varieties of apple the treatments were ineffective. Treatment with 0·01 molar potassium permanganate before and after the hormone treatment did not increase the rooting response.

Biale and Halma

Biale and Halma (1938) treated cuttings of citrus and other sub-tropicals with solutions of indolyl-acetic acid at various concentrations. They used cuttings of three types, namely (*a*) single leaves, (*b*) mature cuttings, and (*c*) immature cuttings, and found that the range of effective concentrations varied considerably not only between species, but also between the three types of cutting of the same species.

Treatment increased the number of roots, but the effect was much more marked in species which root readily without treatment. They considered that the time of the year when the cuttings are taken and the condition of the parent tree are important factors in evaluating the effect of treatment.

Stuart and Marth

Stuart and Marth (1937) found that cuttings of *Ilex opaca*, which were set in the propagating bed on August 27th and treated on November 12th nearly three months later, responded well. They also found that slitting the epidermis at the base of the cutting gave a better distribution of roots.

Oliver

Oliver (1938) tested the effectiveness of indolyl-butyric acid, and also some commercial root-forming preparations, Hortomone A, Hormodin A and Auxilin, in promoting root-formation of greenwood cuttings. The response of each variety tested varied with the light, temperature and humidity conditions during the treatment period, the degree of lignification of the cuttings and the pH of the rooting medium.

Evenari and Konis

Evenari and Konis (1938) treated dormant cuttings of olive, fig and certain rosaceous plants by applying indolyl-acetic acid by the solution method, or as lanolin pastes, or by the insertion of crystals into the base of the shoots. The effectiveness of the treatments in inducing root formation depended on the method of application, bud development being inhibited by too high a dosage. In the treatment of leafy cuttings the solution method was superior to the paste method, as the lanolin hindered the uptake of water and caused the cuttings to wilt. In certain cases an increased root-formation was obtained by the addition of sugar to the growth substance solution.

Skinner

Skinner (1938) worked with cuttings of many ericaceous plants and found that the percentage of cuttings rooting was increased by treatment with indolyl-butyric acid. Indolyl-acetic acid was found to be less effective. As a rooting medium a mixture of sand and peat was found to give greater success than either sand or peat alone.

Wóycicki

Wóycicki (1938) experimented with *Syringa vulgaris*, *Gingko biloba*, *Rosa polyantha* and *Pelargonium zonale* using solutions of 0·005 and 0·001% of phenyl-acetic acid, phenyl-propionic acid and β-indolyl-acetic acid; immersion times of 12 hours were used with the stronger solutions and 20 hours with the weaker ones. A favourable influence on root formation was noted.

Tubbs

Tubbs (1938) treated tea cuttings with β-indolyl-acetic acid solutions for 20 hours at concentrations of from 1 in 2,500 to 1 in 25,000. The weakest solution gave the most favourable result, but even here the increase in number of cuttings rooting was slight, and not sufficient to warrant the use of the hormone in practice.

Stoutemyer

Stoutemyer (1939) reported very favourable results with the dust method using talc as a carrier with several species of cuttings. The addition of thiourea (a substance which has been known for some time to be effective in breaking the dormancy of buds) to the hormone dust was effective in increasing the root-forming efficiency.

Longley

Longley (1939), using cuttings of certain species of shrubs, found the age of the wood to be of great importance in governing response to treatment.

Chadwick and Kiplinger

Chadwick and Kiplinger (1939) found the solution method of treatment to be more effective than spraying. They considered, however, that while the treatment of softwood cuttings of greenhouse and woody ornamental plants, and cuttings of evergreens decreased the time required to reach the normal rooting percentage, it did not increase the final number of cuttings rooting. In the majority of cases the use of the hormones caused more roots to be produced over a larger stem area ; but the external position of the roots on plants which exhibit specific rooting habits was not changed by applications of growth substances. Plants which are normally difficult to propagate by cuttings, e.g. *Juniperus* spp. and *Hydrangea petiolaris*, were not benefited by treatment.

DeFrance

DeFrance (1939 a and b) found that cuttings of *Arctostaphylos Uva-ursi* and of *Sciadopitys verticillata* rooted well after a 24-hour treatment with a solution of indolyl-butyric acid at a concentration of 2 mg. per 100 c.c.

Angelo

Angelo (1939) treated leaf bud cuttings of raspberry with indolyl-butyric acid (2·2 mg. per 100 c.c. tap water) and with indolyl-acetic acid (3 mg. per 100 c.c.) and found that the amount of rooting was reduced as compared with untreated cuttings. He considered that this poor result was probably partly due to the fact that only arbitrary concentrations were tried, but it was also probably due largely to the fact that, as the buds at the base were immersed during the treatment, these were probably inhibited by the hormone with consequent checking of subsequent growth.

Johnston

Johnston (1939) treated hardwood cuttings of several varieties of blueberry with commercial hormone preparations. No advantage was apparent from the use of these materials in comparison to untreated cuttings.

Kirkpatrick

Kirkpatrick (1939) reported special studies with nine varieties of carnation. Indolyl-butyric acid proved more effective than either indolyl-acetic acid or α-naphthalene-acetic acid. Both the solution method and the dust method were employed. The concentration requirements of all the varieties were approximately the same, but cuttings of varieties difficult to root took longer to respond. Treated cuttings showed early rooting and larger root systems than untreated cuttings.

Builder's sand alone, and a mixture of one-third peat moss and two-thirds sand were tested as rooting media. The mixture was most satisfactory. After planting the cuttings the medium was pressed lightly around, and then heavily watered and this proved more satisfactory than compressing the medium ; subsequently light sprayings sufficed to keep the cuttings in a good condition. The greenhouse temperature was 75° F. by day and 70° F. at night ; the response fell off greatly at lower temperatures. The greenhouse had a moderately heavy coat of white paint for shading.

Bottom heat was not tried on all varieties, but on those tested this method of heating speeded up rooting. Electrical heating maintained an even bottom temperature of about 80° F. No noticeable difference was found in the final number of roots between cuttings with bottom heat and those without.

The most effective concentration found in the immersion method was 5 mg. of indolyl-butyric acid per litre of water for a 24 hour period. For the dust method 2 mg. of indolyl-butyric acid per gram of talc was best ; with these strengths effective rooting without injury resulted.

The dust method was carried out as follows :—Basal portions of the prepared cuttings were first moistened by dipping in water ; the moistened bases were then dipped in the powder, and tapped on the side of the container to remove excess powder. After receiving their application of powder the cuttings were planted directly. Moistened cuttings responded much better than dry cuttings and finer dust mixtures were much more active than coarse.

Kirkpatrick (1939) also obtained good responses with special varieties of lilac (*Syringa vulgaris*) using indolyl-butyric acid applied by the solution method.

Hubert, Rappaport and Beke

Hubert, Rappaport and Beke (1939) reported results with many different varieties of cutting after treatment with hormone preparations. The cuttings were rooted in frames in a glasshouse. They observed that cuttings placed nearest the outer wall of the house always rooted poorly, and they considered this to be due rather to a poor light intensity than to a temperature effect.

Among the important factors affecting the rooting response were :—

(*a*) The rooting medium

The percentage of rooted cuttings of both treated and untreated cuttings varies enormously in different media. Using *Aucuba japonica* and *Skimmia oblata* as test plants ten different media were used, namely, firwood soil, oakleaf soil, sawdust, river sand, coal ashes, peat and sand, peat, garden soil, rotting refuse and loamy sand. A mixture of peat and sand, or peat alone proved to be excellent media for both plants, and in these media untreated cuttings rooted almost as well as cuttings treated with indolyl-acetic acid, while in the other media the treated cuttings always rooted best. They considered therefore that the beneficial effect of the peat media might be due to stimulating substances in the peat itself.

(*b*) Age of cuttings

Using *Vitex Agnus-castus* L. they noted that the age of the cuttings has a marked influence on the rooting response. The basal parts of shoots rooted more readily than the apical portions ; and leader shoots which normally root poorly did not respond to treatment, whilst lateral branches which rarely root without treatment gave 70 per cent rooting with treatment.

(*c*) Wounding

Several species of cuttings responded more favourably to treatment if a portion of the epidermis at the base was removed before treatment.

The following results were obtained under nursery conditions :—

Azalea sp. Woody cuttings of several species rooted well after treatment with indolyl-acetic acid and indolyl-butyric acid by the solution method, but softwood cuttings of the same species rooted poorly ; better results were obtained however by the dust method of Grace.

Eurya japonica Thunb. fol. varieg. Hort. One hundred per cent rooting was obtained with several concentrations of indolyl-butyric acid, whilst controls only rooted 75%. A mixture of 50 mg. indolyl-butyric acid and 125 mg. ascorbic acid (vitamin C) per litre with a treatment time of 24 hours gave especially favourable results.

Conifers *Chamaecyparis Lawsoniana* Parl. var. *Alumii* and Triomf van Boskoop, *Taxus baccata* L. and *Araucaria excelsa* R. Br. Good results were obtained and it was found that a complete immersion of the cuttings in the hormone solutions was much more effective than the mere basal treatment.

Araucaria excelsa R.Br. The solution method and the paste method were not very effective, but the dust method using charcoal instead of talc as the carrier proved very satisfactory. Wounding of cuttings before treatment gave good results and 3-4 longitudinal incisions on the basal part was better than the removal of a part of the epidermis at the same place.

Laurus nobilis L. Cuttings rooted 100% in 6½ weeks after treatment with indolyl-acetic acid 125 mg. per litre ; control cuttings formed no roots in a similar time.

Other species which responded well were *Ligustrum ovalifolium* Hassk. var. *aurea marginata* hort., *Ilex Aquifolium* L. var. *aurea variegata* hort., *Osmanthus Aquifolium* Sieb. and Zucc. and *Cytisus canariensis* Comm.

In general they found indolyl-butyric acid to be more active than indolyl-acetic acid with the majority of species. Solutions which had been used once could be used successfully

for a further batch of cuttings provided the duration of treatment was prolonged. In some cases wounding the base of the cutting and the addition of ascorbic acid to the hormone solution was very effective.

Warner and Went

Warner and Went (1939) obtained good results with many species after treatment with indolyl-acetic acid. With cuttings of species which are normally very difficult to root they obtained successful response by the application of vitamin B_1 and peptone to those cuttings which responded insufficiently to indolyl-acetic acid.

Bailey

Bailey (1939) has reported favourable results with hop cuttings using β-indolyl-acetic acid and α-naphthalene-acetic acid.

Baptist

Baptist (1939) carried out preliminary experiments on the response of cuttings of rubber (*Hevea brasiliensis*) to treatment with synthetic plant hormones and proprietary root-forming preparations. Cuttings taken from the basal part of the main stem of one- and two-year-old seedlings showed marked stimulation after treatment, the number of cuttings rooting being greatly increased. Leafless hardwood cuttings from the main stem of one- and two-year-old buddings, and one- to three-year old branches of budded trees showed no response to hormone treatment. The production of new roots on root cuttings was facilitated by suitable hormone applications.

2. Practical methods for the propagator

A. *Substances to use*

From a survey of the literature it is evident that the three most active substances so far discovered for the stimulation of root-formation in cuttings are indolyl-acetic acid, indolyl-butyric acid and α-naphthalene-acetic acid. All three are active root-formers and can now be obtained in a pure crystalline form from most chemical firms.

B. *Method*

Of the various methods of treatment that have been tried the immersion of the basal ends of the cuttings in a solution of the active substance for a standard time before planting is undoubtedly the most promising so far discovered for practical use.

C. *Preparation of the solutions*

A 1% stock solution of either of the three substances can be prepared by dissolving 1 gram of the acid in 50 c.c. of 95% alcohol and adding a further 50 c.c. of tap water. Each cubic centimetre of this solution then contains 10 mg. of the substance. The stock solutions keep well if stored in a cool dark place until required. Indolyl-acetic acid decomposes most readily and α-naphthalene-acetic acid is the most stable. From this stock solution those of the requisite strength for treatment of the cuttings can easily be prepared by dilution.

One per cent stock solutions of the pure substances can be purchased direct from a chemical firm if desired, and there are also solutions sold under several trade names, with directions for use by adding a specified amount of water. These prepared solutions are very convenient in practice where accurate measuring apparatus is not available.

A selected list of plants which have been treated by various workers and the results obtained is appended and this will serve as a guide for approximate concentrations to use when experimenting with an untried plant.

The various measures of concentration that have been used by various workers in equivalent terms are given in the following table.

Mg. per litre.	parts per million.	
2·5	2·5	1 part in 400,000
5·0	5·0	1 ,, ,, 200,000
10·0	10·0	1 ,, ,, 100,000
20·0	20·0	1 ,, ,, 50,000
40·0	40·0	1 ,, ,, 25,000
80·0	80·0	1 ,, ,, 12,500
100·0	100·0	1 ,, ,, 10,000
200·0	200·0	1 ,, ,, 5,000

D. *Preparation of the cuttings*

It is preferable to use freshly prepared cuttings, and to treat them as soon as possible with the solutions. If this is impossible the cuttings must be kept fresh until treatment by covering with a moist cloth and spraying frequently with water. Stuart and Marth (1938) and Hitchcock and Zimmerman (1938), however, showed that it was possible to keep cuttings of certain species for several months before treatment and still obtain successful results, but this is not recommended for practical use.

From the lower inch of the cuttings which is immersed in the solution the leaves should be removed, as these tend to rot after planting if submerged and thus may exert a detrimental effect on the cuttings.,

E. *Treatment of the cuttings*

The treatment consists simply in immersing the bases of the cuttings to a depth of about one inch in the solution. A convenient time for immersion is 24 hours. During the immersion period it is advisable to shade from direct sunlight, otherwise water loss may be so rapid as to cause the cuttings to wilt with fatal results. After the treatment the cuttings are rinsed and then set in the rooting medium.

F. *Important details*

It is essential to bear in mind that the plant is a delicate living organism and therefore to ensure the best results the dose of hormone must be administered with great care. To obtain the maximum rooting response the dose of hormone which the cutting receives must fall within narrow limits. It is therefore imperative to use the right concentration of solution for treatment. With excessive doses injuries will be caused such as the formation of masses of stunted roots, excessive swelling of the stem, or decay of stem tissue and roots which may result in early death of the cutting. An effective treatment is generally accompanied by some swelling of the stem upwards from the base of the cutting, and subsequent profuse root formation.

Unfortunately no single treatment is effective for all species of plants ; in fact even varieties of the same species may vary in their requirements for optimal rooting response. It is therefore suggested that the intending propagator should examine the list of treatments in the index which have proved effective for species as near as possible to the material which he is using, and then run a preliminary trial using ten or twenty cuttings as a unit with solutions at the effective strength stated, and also double and half this strength.

It is probable that the effectiveness of any treatment depends to a large extent upon the amount of hormone solution passing into the cutting. Any factor therefore which influences the rate of absorption of the solution, such as temperature, humidity and light intensity, or the amount of leaf surface on the cuttings, will affect the response obtained.

G. *Care of the cuttings during the rooting period*

It should be emphasized that after treatment the cuttings need the same careful handling as is normally given by the propagator. The index again may serve as a rough guide for the correct rooting medium to select. For exact experiment a pure well-washed sand of medium coarseness has much to recommend it, as one can then be reasonably sure that the medium is free from traces of extraneous substances which may affect the rooting response ; but it will not necessarily give the maximum response for all species.

Hitchcock and Zimmerman (1936) recommend a mixture of half peat and half sand for many herbaceous cuttings.

H. *Difficult species*

With species, which are easy or only moderately difficult to root without treatment, optimal treatment rarely fails to result in increased root formation, and the shortening of the time required for roots to form thus ensures a saving of time and the possibility of handling many more cuttings during the season. With species very difficult to root, however, a response is not always easy to obtain, and the use of the hormones will not replace the careful attention to details necessary without their use. The selection of the most suitable material ; the age of the wood ; the health of the parent plant ; the care of the cuttings while in the rooting medium ; the taking of precautions to minimize losses from disease all remain essential considerations for successful results. The use of these substances in propagation is as yet a new technique, and it is therefore premature to say that some species will entirely fail to respond. It is, however, certain that with these difficult subjects cuttings at certain stages of growth will fail to respond, although the limited success which has been obtained by various experimentors with certain obstinate types lends encouragement to continued trials, varying the treatments and using cuttings at other stages of growth.

I. *Subsequent growth*

If the treatment is optimal the subsequent growth of the treated cuttings should be at least as good as in those rooted in the normal way.

J. *Testing the activity of solutions used*

On occasion the propagator may be doubtful as to the activity of the solutions which are being used for treatment, as the solution may have been kept in stock for some considerable period, and he may therefore wish to be assured of its continued potency. The pea root test of Went (1934) already described is much too laborious to satisfy this need for the practical man, and, moreover, requires constant conditions of temperature and humidity such as can only be obtained in a well-equipped scientific laboratory.

Recently, however, Hitchcock and Zimmerman (1938) have found that single leaf cuttings of the tomato offer a simple and convenient test object. Two or three leaves from the middle portion of young tomato plants bearing from 8 to 9 leaves are severed at the base of the petiole. These leaves are then treated exactly like other cuttings, the basal ends of the leaf stalk are immersed to a depth of about 1 inch in the test solution for 24 hours, while control leaves are immersed in tap water for a similar period. After the treatment period the excess solution is rinsed off and the cuttings are then set in sand or a mixture of sand and peat moss in a propagating frame. Treated cuttings root in five to seven days, whereas meanwhile few roots emerge from control cuttings. Differences at this stage should be apparent to the eye, but if so desired the number of roots can be counted.

Hitchcock and Zimmermann claim that this test besides being extremely simple, cheap and easy to perform is highly sensitive and will give accurate indications even with relatively low concentrations (0·01-3·0 mg. per litre) of hormone solutions.

K. *The dust method*

(*a*) Preparation of the dust

The dust method, introduced by Grace (1937) and since used by several other workers, has been found to be quite effective with cuttings of a number of different species. The synthetic hormone, if not already in a finely divided state, should be ground to a fine powder and then mixed thoroughly with the dust carrier by shaking well. Talc, mercurial dusts, or charcoal have all been found to be effective carriers.

Stoutemyer (1939) prepared dusts by dissolving the hormone in 95% alcohol, and this solution was then stirred into talc to make a pasty mixture. The preparation was then dried in the dark with a fan, and stirred occasionally with a glass rod during the drying period. He

claimed that a powder entirely free from lumps was thus obtained. The dry dust was stored in glass containers in a cool place in the dark. Dusts containing 500 or 1,000 parts of hormone to a million parts of carrier are effective with many species.

(*b*) Treatment

The treatment consists simply in dipping the basal ends of the cuttings into the dust to the depth of about 1 inch, and then removing excess powder by light shaking or tapping. The success of the method naturally depends to a large extent on the right amount of dust adhering to the cutting; if the cuttings are too wet, excessive dosage may result in their subsequent death, whereas if the cuttings are too dry insufficient will remain on them. After the treatment the cuttings are planted directly, and great care must be taken not to rub the dust off in inserting them in the rooting medium. It is therefore advisable to make a hole in the medium with a knife before inserting the cutting.

(*c*) Advantages of the dust treatment

The chief advantage of the dust method of treatment lies in the fact that the cuttings may be planted immediately after treatment, thus saving a great deal of time. Moreover it is claimed that the dusts have a greater latitude of dosage than solutions, which would obviate the necessity of preparing many different concentrations for different species. The dust method is undoubtedly effective in hastening the rooting of easy species; but more evidence is necessary of its efficiency as compared with the solution method for cuttings of species normally difficult to root.

IV. THE MECHANISM OF INDUCED ROOT-FORMATION

1. The action of plant hormones in controlling root-formation

Cooper (1935, 1936) working with lemon cuttings observed that treatment at the base with a strong solution of indolyl-acetic acid caused the localized formation of a great number of roots. When, however, the treated basal portions were cut off soon after treatment, and the cuttings were then again treated, very few more roots were initiated than in an untreated cutting. He therefore suggested that other substances already present in the cuttings accumulated at the base under the influence of the original treatment with indolyl-acetic acid and were removed when that portion was cut off. In a later paper Cooper (1938) using the *Avena* test estimated the amount of hormone present in cuttings after treatment. Portions of cuttings, some of which had been treated at the apex and some at the base with indolyl-acetic acid, showed large amounts of hormone in the bark immediately after treatment, but about 90% of the auxin disappeared during the first day. Very little hormone was recovered from the bark at the apex of cuttings which had been treated at the base with 0·001, 0·005 and 0·02% indolyl-acetic acid. Moderate amounts of auxin were recovered from the basal portions when the cuttings were treated at the apex with these solutions; however, with the 0·02% solution the amount recovered at the base was small as compared with that at the apex. While approximately the same amounts of auxin could be recovered from treated apple (Delicious) and lemon (Eureka) cuttings, yet the lemon cuttings responded by increased root formation, while none of the apple cuttings produced roots. Cooper therefore concluded that apple cuttings are lacking in certain internal substances necessary for root formation, and concluded that with lemon cuttings the action of the basal treatment with indolyl-acetic acid is to cause the downward transport of a substance or substances which are necessary for root formation which thus became concentrated in the basal region. A similar conclusion regarding the rôle of an internal factor in root formation was reached by Went (1938) from experiments with etiolated pea cuttings. He found that if a cutting were divided into a number of sections and each treated with a high concentration of indolyl-acetic acid, the total number of root primordia produced on these sections was about the same as on an intact cutting similarly treated. He therefore suggested that the number of roots produced is determined by internal substances which limit root production, even though auxin is present in excess. The bulk of the root initials were formed

on sections some distance from the apex, and on this theory these must therefore have contained more of these substances. When indolyl-acetic acid was applied to the apex of the uppermost one-eighth of a cutting, only a few primordia were formed at the top. The treatment therefore appears to have mobilized some other substance from the lower parts of the cutting.

Hellinga (1937), however, using *Coleus* cuttings, found that a second treatment of cuttings at the new end exposed by cutting off the originally treated base caused the production of more roots when the cuttings were placed in sugar solutions, and Pearse (1938a) using dormant willow cuttings treated with indolyl-butyric acid obtained a similar result even without the presence of a sugar solution. Dorfmüller (1938) and Hitchcock and Zimmerman (1938) also repeated Cooper's experiment with different species and obtained renewed root formation after a second treatment.

It is certainly clear that factors inherent in the plant tissues are important in governing the response to treatment with synthetic hormones. Thus numerous workers using widely different plants have found that increased root-formation after treatment occurs only when the cuttings used are in a certain stage of growth. This optimal stage, however, varies widely, some species responding best when the cuttings are taken while in active growth, while others react better when growth is slowing down, or has ceased. Still others have so far failed to respond to treatment whatever the stage used.

2. Other substances aiding root-formation

Traub (1938) using cuttings of *Passiflora quadrangularis* and *Bignonia venusta* compared the activity of many different substances in promoting the formation of roots with that of a 0·02% solution of indolyl-butyric acid. Tetra furfuryl alcohol (0·05 and 0·01% solution), calcium furoate (0·1% solution), nicotine (0·01%), sodium naphthol-4-sulphonate (0·01%), naphthalene tetrachloride (saturated solution in 0·5% alcohol), I-proline (0·05%), anthracene (saturated solution in 0·5% alcohol), anthra quinone-b-sulfonic acid (0·01%), anthranilic acid (0·1%) and salicylidene acetamide ($\frac{1}{4}$ saturated solution) were found to have an activity equal to that of the indolyl-butyric acid solution, while many other substances showed activity to a lesser or greater degree. These tests, however, need repeating with different species and with a wider range of concentrations.

Blattny and Robek (1937) found that the application of 1:1000 solution of bacteriological methylene blue (tetramethyl-thioninchloride) free of zinc, for 30 minutes, stimulated the formation of roots and general growth of *Humulus Lupulus* cuttings. Cuttings so treated produced roots four times as long and in weight 31% greater than untreated cuttings.

Grace (1938) applying substances to cuttings of easily rooted plants found that coumarin, vanillic acid, 1 and 2 γ-naphthyl-butyric acid and sulphanilamide gave responses comparable to that shown by both β-indolyl-acetic acid, and α-naphthalene-acetic acids, while to a lesser degree piperonal, methoxy-salicyl aldehyde, and vanillin also showed some activity.

Bausor (1939) has reported on the activity of β-naphthyloxyacetic acid. Applied in various concentrations in lanolin as a paste to intact stems amd leaves of *Ocimum basilicum* L., *Mimosa pudica* L., *Eranthemum nervosum* R.Br., and *Lycopersicum esculentum* Mill., curvatures of stems and leaves resulted from unilateral application and in *Ocimum* and *Lycopersicum* were subsequently followed by the formation of roots over large areas of the stem.

Honey

Oliver (1939) has claimed that honey has a definitely stimulating effect on the rooting of cuttings of *Thuja occidentalis pyramidalis* and of chrysanthemum. The best treatment consisted in standing the cuttings in a 25% solution of honey for 24 hours before planting. A higher percentage of cuttings rooted, and there were more roots per cuttings ; moreover the response was only very slightly less pronounced than that which followed most favourable hormone treatments. The substance or substances stimulating root formation have not yet been isolated from the honey.

3. Substances increasing the efficiency of the hormone treatment

A. *Vitamin B_1*

Went, Bonner and Warner (1938) treated leafy lemon cuttings with indolyl-acetic acid (200 mg. per litre), and then planted them for one week in sand. They were then divided into two groups, and one series was placed for 24 hours in water while the other was treated for a similar time with aneurin (vitamin B_1) solution (1 mg. per litre). They were then returned to the sand and thirteen days later the water-treated cuttings had on the average 8·1 roots, the aneurin treated showed 16·3 roots, while entirely untreated controls produced only 0·3 roots per cutting. Even more conclusive results were obtained with leafy *Camellia* cuttings, and these workers therefore concluded that vitamin B_1, if applied at the appropriate time after the formation of root initials by the hormone treatment, greatly increased the root development of cuttings, and so may become as important in nursery practice as are the root-forming substances themselves.

Pearse (1939) using softwood cuttings of deciduous fruit trees tried a similar treatment with vitamin B_1, but was unable to increase the percentage of cuttings rooting, although the rooted cuttings showed a tendency to grow more strongly after transplanting from the frames.

B. *Carbohydrates*

Went and Thimann (1937) found that treatment with dextrose or sucrose in conjunction with indolyl-acetic acid increased the number of roots formed on etiolated pea cuttings. The kind of sugar used was of importance, thus sucrose and fructose gave larger numbers of roots than did dextrose. The length of the roots was also influenced, fructose producing the longest roots and dextrose the shortest. The possible presence of inhibiting substances in the sugar was also indicated by the fact that sucrose purified by ether extraction produced longer roots than untreated sugar.

It appears improbable that in green cuttings, which normally contain ample carbohydrate reserves root formation should be limited by lack of sugar. Evenari and Konis (1938), however, using *Vitis* cuttings claim to find a beneficial effect of applying sugar in addition to the hormone treatment.

C. *Potassium permanganate*

Brase (1938) working with deciduous fruit tree cuttings gave a treatment with 0·01 molar potassium permanganate both before and after treatment with indolyl-butyric acid, but found no increase in the effectiveness of the hormone.

D. *Amino-acids and Bios*

Went and Thimann (1937) state that the amino acids with the exception of tryptophane do not promote root formation when applied to pea cuttings ; the action of tryptophane is probably due to its conversion by the plant to indolyl-acetic acid.

Yeast extract was found definitely to increase the number of roots formed in the presence of indolyl-acetic acid, and while l-inositol was inactive, biotin was found to increase greatly the number of roots in the presence of indolyl-acetic acid. Amlong and Naundorf (1938) found that the addition of yeast, magnesium nitrate and manganese chloride to indolyl-acetic solution resulted in increased root formation in *Tradescantia*.

E. *Theelin*

Theelin has been stated by Went and Thimann (1937) to increase the number of roots produced by auxin.

F. *Mixtures of hormones*

Went and Thimann (1937) found a combination of auxin and indolyl-acetic acid to produce more roots on etiolated pea seedlings than either alone.

Amlong and Naundorf (1938) found a combined solution of $\frac{N}{2000}$ heteroauxin and

$\frac{N}{2000}$ α-naphthalene-acetic acid to produce a greater number of roots in *Tradescantia* than either of those substances alone at a strength of $\frac{N}{1000}$. The most effective mixture for inducing root formation in *Tradescantia* was found to be $\frac{N}{2000}$ indolyl-acetic acid + $\frac{N}{2000}$ α-naphthalene-acetic acid + 0·02% of yeast extract + 0·02% magnesium nitrate + 0·02% manganese chloride.

4. The correlation between root- and shoot-formation

Czaja (1935) using root cuttings of *Taraxacum*, which very readily regenerate shoots at the apical end and roots at the basal end, found that, if shoot formation was suppressed at the apical end of a cutting by embedding this end in plaster of Paris, shoots and not roots were initiated at the basal end. This was also the case if shoot formation was suppressed by continually cutting slices from the apical end ; if, however, shoot formation was allowed to continue unhindered at the apical end, and a mica plate was inserted at right angles to the long axis of the cutting, in the middle region of the cutting and extending half-way across, shoots were then formed on the semicircle of the basal end directly beneath the mica plate, and roots on the adjoining semicircle. The correlation between shoot-formation at the apical end, and root formation at the basal end of the cutting was thus clearly shown. In a further experiment a paste of indolyl-acetic acid was applied to the apical end, and this effectively suppressed shoot-formation at this end while roots were produced at the basal end. Thus indolyl-acetic acid could replace the shoots in determining root formation at the basal end. Stoughton and Plant (1938) obtained similar results using root cuttings of seakale (*Crambe maritima*). Applying α-naphthalene-acetic acid at the apical end caused roots to form both apically and basally, but if a millimetre slice were removed every 5 days from both apical and basal ends for a period of 8 weeks, 25% of the cuttings subsequently produced shoots at both ends. They therefore concluded that the initial differentiation of meristematic tissue is determined at least in part by the local concentration of hormone, shoots developing at lower and roots at higher concentrations.

Williams (1937) experimenting with *Selaginella* showed that the concentration of indolyl-acetic acid was a factor in determining whether an angle meristem develops as a rhizophore or as a leafy shoot. Howard (1938) working with seedlings of kale, *Brassica oleracea*, treated the stems of decapitated plants with paste containing β-indolyl-acetic acid, and found that adventitious roots were produced, but later adventitious shoots were also formed, and again when the supply of the hormone was removed. Later still, when the new shoots had grown for some time, a second crop of adventitious roots was produced, presumably under the influence of the hormone now supplied by the developing shoots themselves. This experiment lends additional support to the view that the concentration of hormone exerts an important formative effect on the developing meristems. Lindner (1939) also found that relatively high concentrations of indolyl-acetic acid and of α-naphthylene-acetic acid inhibits shoot production and stimulates root production in portions of horseradish root.

5. Failure to form roots after hormone treatment

It therefore seems clear that with root or shoot cuttings which will regenerate easily, the applied hormones are effective in increasing the number of roots formed, and, provided the appropriate concentration can be maintained for a sufficient length of time, roots will be formed in any portion of such cuttings containing meristematic cells or cells capable of becoming meristematic. The presence of buds or leaves is not a necessary condition for such root formation on root cuttings (Czaja (1935), Stoughton and Plant (1938)).

The fact that Hitchcock and Zimmerman were able to produce roots on leaf cuttings of tomato devoid of buds also shows that the presence of buds is not essential.

It has already been stressed that in practice cuttings of some species entirely fail to respond to hormone treatment while others will only respond readily at certain stages of development.

It is evident that in such cases some other factor or factors must be limiting root formation. In certain cases it is clear that carbohydrate supply functions as such a factor and then additional root formation is induced by merely supplementing the hormone treatment with sugar. In other cases additional treatment with vitamin B_1 and biotin have proved superior to treatment with a single hormone, and a mixture of two hormones is sometimes better than either used alone.

We have seen that many different substances not closely related chemically are active in root formation, yet the particular substance used may have specific effects, for it has been pointed out by Oliver (1938), Hitchcock and Zimmerman (1938), and Pearse (1939) that a qualitative difference exists in roots induced by indolyl-butyric acid and α-naphthalene-acetic acid respectively. The roots formed under the influence of the former substance usually appear more normal and well branched while with the latter substance the roots are often thick and fleshy with few branches. The importance of chemical structure is also clearly shown by the fact that substances closely related differ widely in their activity, thus α-naphthalene-acetic acid is one of the most potent root formers while its isomer β-naphthalene-acetic acid has only a very slight activity, and Tincker (1936) found that, while β-indolyl-acetic acid was highly active, iso-indolinone-3-acetic acid was without activity. It is, then, a curious fact that substances which have little in common chemically produce a similar physiological response, while others more closely related differ widely in their activity.

It is probable that in certain cases failure is to be attributed to lack of the requisite meristems for root development ; on the other hand in some types of cutting the treatment induces callus formation but no roots.

It has been suggested that failure is sometimes due to enzymes which rapidly destroy the applied substance, but Cooper was able to recover the active substance from treated apple cuttings in spite of failure to form roots.

Went (1939) used etiolated pea stem cuttings as quantitative test objects for the root-forming activity of different hormones, and, as the result of dividing the period of auxin treatment into two shorter ones, considered that it was possible to distinguish two separate phases. He tentatively suggested that the first phase of the auxin action was a redistribution of rhizocaline within the stem ; this phase could be induced not only by indolyl-acetic acid, but also by phenyl-acetic acid, γ-phenyl-butyric acid, sodium naphthol sulphonate, and other substances. The second phase he considered to be the activation of this accumulated rhizocaline, which can only be accomplished by indolyl-acetic acid and related substances.

The question remains therefore whether there is a substance as yet unisolated essential for root formation (rhizocaline) as postulated by Bouillenne and Went (1933) and Cooper (1935).

6. Root origin and metabolic activity in response to treatment with synthetic plant hormones

Kraus, Brown and Hamner (1936) decapitated young bean seedlings at the top of the second internode and applied a small amount of lanolin paste containing 30 mg. of indolyl-acetic acid per gram of lanolin to the cut surface. Controls were left untreated, or treated with pure lanolin. Histological studies were made of material collected and preserved at 6 hour intervals up to a total period of 168 hours. Several hours after application the epidermal cells enlarged slightly and divided in the radial plane ; the cells of the cortical parenchyma enlarged and those near the endodermis became meristematic, starch and chloroplasts rapidly disappearing. The cells of the endodermis were highly responsive, and active division was noted shortly after treatment. The derived cells differentiate as xylem and phloem elements and large, often multinucleate, parenchyma cells. Some remain actively dividing and others give rise to adventitious roots. The cells of the pericycle proliferate slightly. The parenchyma of the primary phloem responds similarly to the endodermal cells, and the parenchyma of the secondary phloem also undergoes marked proliferation.

Borthwick, Hamner and Parker (1937) decapitated young tomato seedlings above the second leaf and applied a mixture of 20 mg. of indolyl-acetic acid in 1 gm. of lanolin to the cut surface. Control plants were excised in the same manner, and were treated with lanolin only. The internode treated with indolyl-acetic acid enlarged at about the same rate as normal

internodes below, but control ones failed to enlarge. After treatment the first result was an enlargement of the cells of the epidermis and cortex. Many of the tissues became meristematic, the zone of activity being almost entirely confined to a region of 0·5-2 mm. from the treated surface. Nearly all the parenchymatous cells in this zone divided, the endodermal cells, external and internal phloem parenchyma, and pith cells adjacent to the internal phloem exhibiting the greatest activity. The epidermis, most of the pericycle sieve tubes, and companion cells and internal fibres showed little or no meristematic activity. A ring of adventitious roots was formed around the stem as a result of divisions in the external phloem, and another ring of roots was formed near the pith from cells of the internal phloem and adjacent pith. Nitrates were more abundant in untreated stems, but the concentration of protein increased, especially in the areas where cell division was rapid, and starch disappeared from the cells.

Czaja (1938) also demonstrated that treatment of plants with indolyl-acetic acid affected their metabolism and the rate of transfer of carbohydrate.

Mitchell and Martin (1937) applied 3% β-indolyl-acetic acid in lanolin to the first internode of etiolated bean seedlings (*Phaseolus vulgaris*). Galls and adventitious roots were developed at the point of application. Analyses of treated and untreated plants showed that materials were conducted from the cotyledons upward only as far as the point of treatment in the plants receiving indolyl-acetic acid, although there was no evidence of mechanical blocking.

Mitchell and Hamner (1938) decapitated seedlings of *Phaseolus vulgaris* growing in the light, above the second internode, and applied lanolin containing various concentrations of indolyl-acetic acid to the cut surface. With concentrations above 0·00185%, the development of axillary buds was retarded, and the stem ends produced tumours and roots and the parts of the plants near the point of treatment increased more in fresh and dry weight than did similar parts of untreated plants. Lower concentrations retarded the buds less, no roots were formed, and the tumours were much smaller. Plants, from which the axillary buds were removed, were treated with dilute concentrations and showed final dry weights between 6% and 11% greater than control plants at the end of 6 days, although the leaf area was not appreciably greater. The effect was most marked when the plants were grown in light of high intensity.

Alexander (1938) obtained similar results, and showed that carbohydrates were translocated towards the point of treatment.

Stuart (1938) and Mitchell and Stuart (1939) worked with cuttings of *Phaseolus vulgaris* treated with 0·002% or 0·01% indolyl-acetic acid solutions for 3 hours. After treatment the cuttings were set in sand, and harvested at different periods up to 15 days, each sample being divided into roots, hypocotyls, first internodes, primary leaves, petioles and tips. Fresh weight, dry weight, total and insoluble nitrogen, reducing sugars and sucrose were determined for each sample. Treatment with the 0·01% solution increased the dry weight of the hypocotyls and roots, and decreased the growth of the first internode and of the shoot tips. The dry weight of the primary leaves was not appreciably altered and the total weight of the whole cutting was not increased. During root formation nitrogen was transported to the first internodes and hypocotyls, but subsequently disappeared. The sugar content of the cuttings was reduced.

Goldberg (1938) applied a 3% mixture of β-indolyl-acetic acid in lanolin to decapitated stems and to unwounded internodes of cabbage plants, grown at high and low levels of nitrogen. All tissues of the stem responded to some extent to the treatment, especially those of the phloem, medullary rays and pith ; the cambium, cortex, endodermis and xylem showed a moderate, and the epidermis and pericycle a weak response. Adventitious roots were developed from medullary ray and phloem tissue, and some internal roots were produced from pith cells adjacent to the primary xylem. The reactions were slower in low nitrogen plants.

OTHER EFFECTS OF HORTICULTURAL IMPORTANCE

1. On germination of old or damaged seed

Amlong and Naundorf (1937) induced increased percentage germination in old stored seed or seed reluctant to germinate by immersion for 24 hours in 0·01 or 0·001 N indolyl-acetic acid solution.

Grace (1938) conducted experiments with cereal grains and found that the reduction in germination and early growth resulting from formaldehyde treatment can be largely overcome by adding α-naphthalene-acetic acid or indolyl-acetic acid to the disinfecting solution. The optimum concentrations of the hormones for individual varieties were between 0·01 and 5 p.p.m. Similar results were also obtained with hormones after copper sulphate and hot water treatment.

2. On plant growth generally

A. *Following seed treatment*

Cholodny (1936) soaked oat seeds in a solution of β-indolyl-acetic acid (1-2 mg. per 10 c.c. water) for 24-48 hrs. at 18-20° C. Seeds were also soaked in a solution of growth substance obtained from maize endosperm for a similar period. He claimed that the seeds treated with β-indolyl-acetic acid gave considerably stronger plants than untreated controls, and that the yield in grain at harvest was 55% higher. There was however no difference in the date of flowering. The plants treated with the preparation from maize endosperm lagged behind the controls at first but were later far ahead and flowered twelve days earlier.

Grace (1937) treated seeds with synthetic growth-promoting substances incorporated in talc or standard mercurial dust, and at appropriate concentrations both root and shoot growth was markedly stimulated. For cereal seeds half an ounce of dust was applied per bushel of seed. Some optimum treatments expressed as parts by weight of hormone per million parts by weight of seed were:—Wheat (*a*) 2 p.p.m. indolyl-acetic acid, (*b*) 2 p.p.m. indolyl-acetic acid + 2 p.p.m. α-naphthalene-acetic acid, (*c*) 2 p.p.m. indolyl-butyric acid. Treatment (*a*) gave 65%, (*b*) 103%, and (*c*) 55% increase in length of the roots as compared with untreated seed. The dry weights of the shoots were also increased up to 20%. For barley and soya bean seed 2 p.p.m. and 10 p.p.m. respectively of α-naphthalene-acetic acid gave optimum responses. In a later paper (1938) Grace describes experiments in which wheat seed was treated with a solution of α-naphthalene-acetic acid at concentrations from 0·01 to 100 p.p.m. In some cases there was a slight increase in the percentage germinating but the dry weights of the plants, after growing in soil, failed to show any appreciable increase from the hormone treatment.

McRostie, Hopkins and Grace (1938) applied concentrations of indolyl-acetic acid at 2, 5 and 10 p.p.m., and of α-naphthalene-acetic acid 2, 5, 10, 20, 50 and 100 p.p.m. and 2 p.p.m. of a mixture of indolyl-acetic acid and α-naphthalene-acetic acid to ten varieties of winter wheat before planting in a replicated field trial. One half of each plot received seed dusted with Cerasan (an organic mercury fungicide) only, while the other half received an equal quantity of seed of the same variety dusted with Cerasan together with phytohormone. Cerasan was used throughout at the rate of ½ oz. per bushel, while the hormone concentrations given above are parts per million by weight of seed treated. The dusts were applied a few hours before planting, each lot of seed and dust being shaken together in a glass bottle, to give uniform distribution.

The authors state that some differences between the hormone-treated and untreated sub-plots in respect of early growth were apparent to the eye. There were also significant differences in respect of straw production, and of yield and weight per bushel of grain. Different varieties responded differently to the same treatment, and in general all treatments tended to reduce the nitrogen content of the grain. The maximum increase of grain yield of a variety was 13%, and of straw production roughly 20%. The results varied greatly, however, with different varieties, and the authors hesitate to reach any general conclusion before further investigation of dosages, varietal characteristics and seasonal effects have been undertaken.

Chailakhyan and Zhdanova (1938) soaked seeds of various different species such as summer and winter wheat, oat, millet, vetch, hemp, white mustard, perilla, flax and peas for 24 hours in solutions containing 10, 25 and 50 mg. of heteroauxin per 100 c.c. water. The effect of this treatment on the subsequent growth varied with the different species, the growth of oats was slightly accelerated, that of flax and vetch was checked, that of mustard was decreased during the early growing period and accelerated later. In many cases, however, the plants reached the fruiting stage earlier.

Davies, Atkins and Hudson (1937) soaked seeds of *Avena sativa*, *Lepidium sativum* and *Brassica alba* in solutions of various concentrations of β-indolyl-acetic acid. The germination and subsequent growth of the seedlings, which were germinated in Petrie dishes, was retarded at all concentrations used. With ascorbic acid, however, a stimulating effect in both root and shoot growth was obtained at low concentrations.

Amlong and Naundorf (1937) soaked seeds of several different varieties for 24 hours in solutions of β-indolyl-acetic acid of concentrations ranging from 0·01-0·001 N. After this treatment the seeds not only germinated better but also developed into larger plants. Thus radishes showed an increase of 98% of root weight after treatment of the seeds with 0·001 N solution, and sugar beet seeds soaked in 0·01-0·001 N solution produced plants with larger leaves. In a later publication (1938) the same authors reported the results of further experiments and claimed that the soaking of sugar beet seed prior to sowing in a solution of indolyl-acetic acid 0·01 N resulted in a 157% increase in the weight of the crop, 129% leaf increase and 123% increase in sugar content. Treatment of seed potatoes however had practically no effect on the yield.

Templeman (1939) treated seeds of white mustard for 24 hours before planting in solutions of sodium β-indolyl-acetate 50, 100, 200 and 500 mg. per litre, and sodium α-naphthyl-acetate 5, 10, 20 and 50 mg. per litre. All the treatments with sodium β-indolyl-acetate produced plants with longer stems in the early stages of growth, but there was no significant increase in the dry weight of the tops in any treatment after three months' growth.

Thimann (1936) and Thimann and Lane (1938) found that after treatment of the seed of *Avena* and *Triticum* with relatively high concentrations of indolyl-acetic acid, the general vegetative growth of the shoot is accelerated, the leaves may become longer and wider, and the dry weight of the plants may be increased more than 50%. There is also a slight hastening of flowering, but this is most likely due to the accelerated vegetative growth. This general acceleration was considered to be an after-effect, due to the action of the auxin on the root system.

Stier and du Buy (1939) treated tomato seeds with hormone talc dust mixtures, and subsequently treated the young plants with solutions of either indolyl-butyric acid or α-naphthalene-acetic acid at the time of transplanting to the field. Certain combinations and the use of appropriate concentrations resulted in (*a*) marked acceleration of the time of anthesis of the flowers, (*b*) production of a greater yield of fruit during the first month of the fruiting period, and (*c*) a greater total yield of marketable fruit for the entire season. The effective concentration of α-naphthalene-acetic acid in the dust mixture for seed treatment was considerably lower than that of indolyl-butyric acid. α-naphthalene-acetic acid in talc in concentrations of 10,000 p.p.m. and 100,000 p.p.m. caused marked inhibition in the rate of seed germination, and time of flowering of the plants in the field. Greatest acceleration in flowering and fruit production, and the greatest total yield was obtained by the treatment of 50 seeds with approximately 15 mg. of a dust mixture consisting of 10 mg. of α-naphthalene-acetic acid to 10 grams talc, followed by dipping the plant roots in an aqueous solution of indolyl-butyric acid (10 p.p.m.) for about 2 seconds at the time of transplanting. α-naphthalene-acetic acid in similar concentrations as a treatment at transplanting time appeared to be inhibitory to flowering and fruiting of the plants in the field in all instances except in one case when indolyl-acetic acid was used in the dust medium for seed treatment.

B. *Following treatment of intact plants or their culture medium*

Hitchcock and Zimmerman (1935) showed that synthetic hormones applied as solutions to the soil of plants growing in pots was absorbed by the roots, and responses such as epinasty

of the leaves, and root formation on the stem occurred. The dry weights of the plants were not determined after such treatment, but from visual observation it was apparent that the growth of the tops was retarded. Pearse (1937) sprayed young tomato plants with a 0·1% solution of either phenyl-acetic acid or indolyl-butyric acid. A daily application was given and resulted in increased height of the plants, and longer petioles and internodes. The balance between parts of the plants was altered after one and two weeks' treatment, phenyl-acetic acid depressing root and leaf growth but increasing the growth of stem and petiole ; indolyl-butyric acid depressed leaf-growth, but increased that of root, stem and petiole. The total dry weight of the plants, however, was never higher than that of the controls. The water content of the plants was increased by the treatments. In a later communication Pearse (1937) described the effects of applying β-indolyl-acetic acid to broad bean plants grown in water cultures ; 1 c.c. of a 0·1% aqueous solution was applied daily either in the culture solution to the roots or a similar amount was applied to the tops by spraying. The growth in length of the roots was greatly retarded by the former treatment, but they were thicker and more abundant, so that total dry weight of root was not altered, whilst spraying slightly decreased the weight of the root system without altering its form. The total dry weight of the plants was decreased by either treatment.

Marmer (1937) grew wheat seedlings in a wide range of concentrations of β-indolyl-acetic acid, β-indolyl-propionic acid and β-indolyl-butyric acid at pH 4·6 and pH 7·5. At both pH levels the growth of the primary root, coleoptile, and first leaf was decreased, but the number of secondary roots was increased. More lateral roots were formed at a low than at a high pH.

Leonian and Lilly (1937) attempted to stimulate the growth of fungi, algae, and of detached roots and shoots of aseptically germinating cereal grains by various concentrations of β-indolyl-acetic acid ranging from 1 part in 10,000 to 1 part in 10,000,000 of nutrient medium. Without exception it was found that the higher concentrations proved toxic, and the lower concentrations failed to induce any stimulation.

Macht and Grumbein (1937) studied the action of extremely dilute concentrations of indolyl-acetic, indolyl-butyric, and α-naphthalene-acetic acids on the root growth of *Lupinus albus* seedlings, and found that the growth of the roots was definitely stimulated after a brief exposure to a very weak solution of any of the three substances applied. Longer exposures to the same concentration and exposures for the same period to a higher concentration, however, invariably produced a toxic or inhibitory effect. A typical example may be cited : an exposure of 15 minutes to a solution of indolyl-acetic acid at a concentration of 1 in 1,000,000,000 resulted in an increase in root growth whilst an exposure of 30 minutes to the same concentration caused a decrease.

Grace (1937) reported that the growth of young seedlings of tomato, nasturtium and salvia, watered daily with 50 c.c. of a nutrient solution containing hormones, was greatly increased. The optimal concentrations of either indolyl-acetic acid, or α-naphthalene-acetic acid lay between 1/10 and 1/100 p.p.m. With decreasing concentrations the effect diminished and increasing concentrations led to injury and death. The reaction was most marked in sand cultures, less so in soil, and the extent of the stimulation was greatest in very young plants.

Amlong and Naundorf (1937) reported that spraying plants with indolyl-acetic acid at a concentration of N/100 accelerated vegetative growth, and flowering. Greenfield (1937) and Loehwing and Bauguess (1936) found that the addition of a dilute solution (1 in 15,000) of indolyl-acetic acid to the soil produced a slight acceleration in the growth of young seedlings. This acceleration was not maintained, however, and disappeared after 10 days.

Sayre (1939) using concentrations of 50 mg. α-naphthalene-acetic acid or 250 mg. of indolyl-acetic acid in 50 gallons of water applied one pint of either solution to young tomatoes plants at transplanting time. The applications were not effective in increasing yields and tended to delay maturity.

Templeman (1939) carried out pot-culture experiments in which solutions of β-indolyl-acetic acid, α-naphthalene-acetic acid, skatole and ascorbic acid were applied to plants by spraying on to the foliage and by watering on to the sand. No significant increases in dry matter production were obtained.

Mitchell (1939) sprayed bean plants with aqueous solutions of indolyl-acetic acid containing 300 mg. per litre and found that their growth was repressed, while weaker solutions had

little effect. Solutions containing 10-300 mg. per litre had no appreciable effect on the total growth of marigold plants although marked bending and curling of the leaves occurred after repeated treatments. Solutions of indolyl-acetic acid in oil or in water were also sprayed on oat and bean plants growing in the field but without appreciable effect on their growth ; while the fresh weight of the tops of bean plants growing in the open which were irrigated with solutions of indolyl-acetic acid containing 0·01 and 1·0 p.p.m. indolyl-acetic acid were slightly greater than those of control plants. A similar response could not, however, be obtained with marigold.

The effect of hormones on the lower plants has also been noted. Thus Pratt (1938) grew *Chlorella vulgaris* for three weeks in nutrient solutions to which were added different synthetic hormones. Cell multiplication was markedly increased in the presence of 50 p.p.m. β-indolyl-acetic acid, β-indolyl-propionic acid, or β-indolyl-butyric acid. Concentrations of 10 p.p.m. also caused appreciable stimulation, indolyl-acetic acid being the most effective, and indolyl-butyric acid the least. Similar increases could not be brought about by the addition of glucose to the nutrient solution.

C. *Following treatment of culture medium of intact plants with vitamin B_1*

Bonner and Greene (1938) added vitamin B_1 at the rate of 1·0, 0·1 and 0·01 mg. per litre to the nutrient solution used for sand cultures of various species of plants growing in a glasshouse. The addition of the vitamin was found to increase the shoot growth of species of plants which are normally slow growing ; but had no effect on the growth of fast-growing annual plants. They pointed out that organic manure contains appreciable amounts of vitamin B_1 and the beneficial effects of manure upon plant development may, therefore, be partly due to its vitamin B_1 content.

It is evident from this brief survey that it is as yet too early to reach any definite conclusions, and the effect of hormone treatment on total growth needs further careful investigation, before any recommendations can be made for practical use.

3. On parthenocarpic development

Gustafson (1936) induced the parthenocarpic development of fruits of tomato, pepper, crook-neck squash, egg plant, *Petunia* and *Salpiglossis* by applying 1% lanolin pastes of indolyl-acetic acid and other synthetic hormones to the stigma or cut surface of the style. He failed, however, to secure such fruits in water melon, summer and winter squash and pumpkin, and results with cucumber were also not consistent. Hagemann (1937) obtained parthenocarpic fruits of gladiolus by similar treatments. Gardner and Marth (1937) obtained parthenocarpic fruits of American holly (*Ilex opaca*) by spraying the pistillate flowers with α-naphthalene-acetic acid, indolyl-butyric acid, indolyl-acetic or indolyl-propionic acids of different concentrations. A few parthenocarpic fruits were obtained on strawberry plants with indolyl-acetic acid, but self-sterile varieties of apple and grape gave negative results. Wong (1939) found that indolyl-acetic acid and indolyl-butyric acid of 0·5 and 1·0% strength, applied as lanolin pastes to the ovary, did not induce parthenocarpic fruit in a commercial variety of seedless orange, even though natural parthenocarpy does exist in this type, and Varrelman (1938) sprayed a normally parthenocarpic type of Navel apple (*Malus apetala*) with different concentrations of indolyl-acetic and α-naphthalene-acetic acids and failed to set fruit. In a later communication Wong (1939) was successful in obtaining parthenocarpic fruits of cucumber, watermelon and pepper, lanolin pastes of α-naphthalene-acetic acid being especially effective.

Schroeder (1938) working with tomato found that when a lanolin paste of indolyl-acetic acid (1 in 500) was applied over the entire ovary, the percentage of flowers set compared favourably with normal and hand pollination treatments. The average weight of fruit from the hormone-treated flowers was not however as great. Applications to the stigma or to the end of the cut off style were not nearly so effective.

Gardner and Kraus (1937) made a histological examination of parthenocarpic fruits, and also of those developing after pollination, and found that development proceeds in a normal way without tumours or the formation of root primordia, with the swelling of ovaries through

cell division and increase in size of the cells. There was, however, no trace of an embryo and no development of endosperm.

Gustafson (1937, 1938a, 1938b) found that in many cases after application of hormone the initial growth soon stopped, whereas in other cases the fruit continued until half-grown and then stopped, while in still other fruits growth continued until maturity. Gardner and Marth (1937) found that four sprayings produced a higher percentage set than a single spraying. Gustafson (1939) found that the natural hormone content of ovules and developing seeds is greater than that of other parts of the fruits, and considered it probable that it is produced there. Gustafson (1939) concludes that it is not yet clear whether the applied synthetic hormones are the primary factor in the development of the fruit, or whether they stimulate the production of a natural substance necessary for development.

From the practical standpoint, however, it is sufficient to note that parthenocarpic fruits can be produced in some species by applied substances, but it is doubtful whether this will be of any commercial importance. In some cases a seedless fruit is not desirable, e.g. tomato, and in many other cases the artificially produced fruits have not yet reached the same standard as the natural product.

4. On retardation of fruit buds

Hitchcock and Zimmerman (1938) stated that the growth of flower and leaf buds on fruit trees was delayed by sprays containing α-naphthalene-acetic acid ; it was found that water solutions as well as preparations containing Penetrol (an oxidized sulphonated petroleum product used as a carrier for insecticides) were effective. Pearse and Hwang (unpublished) carried out a field experiment at East Malling in the spring of 1939 in which young apple trees of the variety Cox's Orange were sprayed with various concentrations of α-naphthalene-acetic acid just before and at the time of breaking of the flower buds. The solutions contained 5% ethylene glycol and 0·5% soap with concentrations of α-naphthalene-acetic acid varying from 1 p.p.m. to 800 p.p.m. The results were not favourable, the higher concentrations killed the fruit buds whilst the lower ones were not effective in causing appreciable retardation. Several applications of a dilute solution were also without effect. In addition watery solutions of the hormone were injected into the trees with similar results.

5. On storage of fruit

Traub (1938) has observed that treating unripe fruits with weak solutions of hormones increases their storage life, but that the use of stronger solutions decreases it.

Fruits of *Passiflora edulis*, *P. antiguensis*, tree tomato (*Cyphomandra betacea*), grapefruit (*Citrus grandis*), sweet orange (*C. sinensis*), lemon (*C. Limonia*) and lime (*C. aurantifolia*) were treated with watery solutions of indolyl-acetic acid, indolyl-butyric acid and α-naphthalene-acetic acid or with 1% lanolin pastes. The fruits, which were half submerged in a peat and sand mixture, were treated at the stem or calyx ends with lanolin pastes, or were soaked in hormone solutions. Alternatively the entire fruits were immersed in varying concentrations for 24 hours, or were completely covered with a very thin film of lanolin paste containing the hormone. The solutions of higher concentrations, 0·05%, accelerated, whereas the more dilute ones, 0·01 to 0·001%, arrested senescence in all the types studied.

6. On framework control in fruit trees

Narrow crotch angles in the framework of fruit trees are structurally weak, and are often easily broken. Verner (1939) applied indolyl-butyric acid in lanolin (5-25 mg. per 100 gms. lanolin) to the upper surface of the basal internode of young, elongating apple shoots, and a marked increase in the magnitude of the angle formed by the trunk and the shoot resulted. After the elongation of the basal portion of the shoot had ceased, the crotch angle was permanently fixed.

7. On rate of rooting in transplanted trees

Romberg and Smith (1939) had observed that nursery grown pecan trees usually make very little growth for the first two years after transplanting, and found this to be largely due to the slowness with which a vigorous root system was re-established. Root-forming substances were therefore tested for hastening the development of new roots. Encouraging results were first obtained with root cuttings after applying indolyl-butyric acid in lanolin either smeared on the bases of the cuttings or applied in slits or holes made through the bark, the latter method being superior. Tests were therefore subsequently made with comparable groups of 5-7-year-old pecan nursery seedling trees. A novel method of treatment was used which will therefore be described in detail. Toothpicks were prepared as follows :—the pointed ends of ordinary round toothpicks were cut off leaving the middle portion which was cut to a length of 4 cm. Solutions of indolyl-butyric acid were prepared in 95% alcohol, and the prepared lengths were soaked in these solutions for 24 hours. They were then removed and air dried. In the preparation of toothpicks carrying 4 mg. of the acid, 1 gram was dissolved in 21 c.c. of alcohol. Each toothpick absorbed approximately 0·084 c.c. of solution. In applying the treatments holes were bored transversely through the roots with an electric drill and the prepared toothpicks inserted. The toothpick method was found to be very effective, and economical of material. Toothpicks carrying 0·5, 1, 2 and 4 mg. per toothpick were tried, and those carrying 4 mg. proved most effective, and greatly increased the production of new roots.

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Abelia grandiflora Rehd.	Yerkes, 1938	7/1	Indolyl-butyric acid 5 mg. per 100 c.c. 21 hrs.	34	—	—	93	33	Growing wood best. Little response to treatment on harder wood.
Acalypha Wilksesiana Muell. Arg. f. *obovata* Hort.	Hubert and Beke 1938	16/12	β - indolyl - acetic acid 100 mg. per litre 22 hrs.	11	Sand	—	100	100	Treated cuttings had many more roots.
A. Wilksesiana Muell. Arg. f. *Hamiltoniana* Hort.	Hubert and Beke 1938	16/12	β - indolyl - acetic acid 100 mg. per litre 22 hrs.	11	Sand	—	100	100	Treated plants had more roots per cutting.
Acer palmatum Thunb.	Hitchcock and Zimmerman 1936	—	β - indolyl - acetic acid 50 mg. per gram lanolin paste.	—	Sand/ Peat 1/1	—	46	5	Shoots treated with paste while still attached to parent tree and cuttings taken from 1 to 3 weeks later.
A. saccharum Marshall	Scholz 1937	17/7	Indolyl - acetic acid 10 mg. per litre 48 hrs.	40	Sand/ Peat 1/1	—	100	0	Cuttings planted directly rooted 33·3%.
Actinidia chinensis Planchon	Scholz 1937	17/7	Indolyl - acetic acid 100 mg. per litre 48 hrs.	40	Peat/ Sand 1/1	—	100	60	
Aleurites moluccana Willd.	Hubert and Beke 1938	—	Indolyl - acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Alternanthera amoena Voss	Hubert and Beke 1938	3/12	Indolyl - acetic acid 50 mg. per litre 6 hrs.	7	Sand	15	100	100	More roots per cutting after treatment.

* Where favourable response was obtained the optimal treatment is given here.

† The number given here signifies that this number was treated and that an equal number was used as control.

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Amorpha	Warner and Went 1939	3/4	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	33	Sand	12	8	0	Hardwood cuttings
Amorpha	Warner and Went 1939	3/4	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	33	Sand	8	87	50	Softwood cuttings.
Annona Cherimola Mill.	Hubert and Beke 1938	—	Indolyl - acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Apple (Malling Rootstock No. 1)	Pearse 1939	30/6	Indolyl - butyric acid 20 p.p.m. 24 hrs.	24	Sand	10	100	0	Cuttings from stool-bed shoots.
Apple (Malling Rootstock No. IX)	Pearse 1939	11/5	α - naphthalene - acetic acid 5 p.p.m. 24 hrs.	24	Sand	10	30	0	Cuttings from bedded rootstocks.
Apple (Scion variety Bramley's Seedling)	Pearse 1939	7/7	Indolyl - butyric acid 15 p.p.m. 24 hrs.	50	Sand	10	50	0	Cuttings from established trees.
Araucaria brasiliana A. Rich.	Hubert and Beke 1938	—	Indolyl - acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Arbutus Unedo L.	Hubert and Beke 1938	—	Indolyl - acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Aristolochia Sipho L'Hérit.	Scholz 1937	29/7	Indolyl - acetic acid 200 mg. per litre 24 hrs.	30	Peat/ Sand 1/1	—	40	0	
Aucuba japonica Thunb.	Hubert and Beke 1938	7/1	Indolyl-acetic acid 50 mg. per litre 8 hrs.	49	Sand	10	90	50	
Azalea arborescens Pursh	Yerkes 1938	28/6	Indolyl - butyric acid 8-10 mg. per 100 c.c. 4 hrs.	63	—	—	60	70	Wood in active growth. Deciduous azaleas withstood somewhat stronger concentrations without injury than Kurume varieties.

A. calendulacea Michx.	Yerkes 1938	18/6	Indolyl - butyric acid 5-10 mg. in 100 c.c. 22 hrs.	73	—	—	40	0	Taken while in active growth. No results from older wood of deciduous azaleas.
A. Carmen	Yerkes 1938	28/6	Indolyl - butyric acid 3-10 mg. per 100 c.c. 4 hrs.	40	—	—	100	30	Twigs still in active growth.
A. Cattleya	Yerkes 1938	6/8	Indolyl - butyric acid 5-10 mg. per 100 c.c. 4 hrs.	36	—	—	79	0	Short laterals better than main branches of all Kurume azaleas.
A. Christmas Cheer	Yerkes 1938	1/6	Indolyl - butyric acid 5 mg. per 100 c.c. 4 hrs.	40	—	—	60	100	
A. Damask Rose	Yerkes 1938	6/7	Indolyl - butyric acid 3-8 mg. per 100 c.c. 4 hrs.	34	—	—	95	65	Short laterals better than main branches of all Kurume azaleas.
A. Débutante	Yerkes 1938	30/6	Indolyl - butyric acid 5 mg. per 100 c.c. 4 hrs.	32	—	—	89	61	
A. Firefly	Yerkes 1938	2/7	Indolyl - butyric acid 3-10 mg. in 100 c.c. 18 hrs.	54	—	—	95	94	
A. Hexe	Hubert and Beke 1938	7/1	Indolyl-acetic acid 50 mg. per litre 8 hrs.	27	Sand	20	85	40	
A. obtusa Lindl. var. *Hinodegirii*	Yerkes 1938	1/7	Indolyl - butyric acid 3-10 mg. in 100 c.c. 20 hrs.	52	—	—	85	75	
A. obtusa Lindl. var. Hinomayo	Yerkes 1938	28/6	Indolyl - butyric acid 5-8 mg. in 100 c.c. 20 hrs.	42	—	—	81	66	
A. japonica A. Gray.	Yerkes 1938	29/6	Indolyl - butyric acid 5-10 mg. in 100 c.c. 4 hrs.	62	—	—	35	0	
A. Kaempferi [= *Rhododendron Kaempferi* which see.—Ed.]	Yerkes 1938	7/7	Indolyl - butyric acid 5-8 mg. per 100 c.c. 4 hrs.	47	Sand/ Peat 1/1	—	85	0	Twigs still in active growth.

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
A. Maxwellii Hort.	Yerkes 1938	18/6	Indolyl - butyric acid 3-8 mg. in 100 c.c. 20 hrs.	47	—	—	100	82	
A. mollis	Yerkes 1938	18/6	Indolyl - butyric acid 3-10 mg. in 100 c.c. 4 hrs.	73	—	—	70	10	
A. mollis Hort.	Scholz 1937	16/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	41	Sand/ Peat 1/1	—	12·5	0	
A. nudiflora L.	Yerkes 1938	29/6	Indolyl - butyric acid 8-10 mg. per 100 c.c. 4 hrs.	62	—	—	73	56	Wood in active growth. Deciduous azaleas withstood somewhat stronger concentrations without injury than Kurume varieties.
A. poukhanensis	Yerkes 1938	28/6	Indolyl - butyric acid 8-10 mg. per 100 c.c. 4 hrs.	63	—	—	67	57	,,
A. Snow	Yerkes 1938	30/6	Indolyl - butyric acid 3 mg. per 100 c.c. 21 hrs.	54	—	—	80	33	
A. viscosa L,	Yerkes 1938	29/6	Indolyl - butyric acid 8 mg. per 100 c.c. 4 hrs.	62	—	—	58	63	
A. obtusa Lindl. var. Yayegiri	Yerkes 1938	13/7	Indolyl - butyric acid 5 mg. per 100 c.c. 4 hrs.	48	—	—	100	67	
Betula pendula var. *Youngii* Schneid.	Scholz 1937	29/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	10	0	
B. verrucosa var. *fastigiata* Hort.	Scholz 1937	21/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	38	Sand/ Peat 1/1	—	21·4	0	

Bougainvillea spectabilis Willd. Crimson Lake	Laibach 1937	—	Indolyl-acetic acid 0·5% lanolin paste.	47	Sand	20	35	0	
Buddleia alternifolia Maxim.	Tincker 1938	July	Lanolin paste (1) $\frac{1}{1000}$ β-indolyl-acetic acid.	—	Sand	—	—	—	Rooting accelerated by treatments.
			(2) $\frac{1}{100}$ α-naphthalene-acetic acid.	—	Sand	—	—	—	,,
Buddleia sp.	Laibach 1937	—	Indolyl-acetic acid 0·01% solution in water.	16	Sand	30	70	0	
Buxus quadrangularis F. Muell.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
B. sempervirens arborescens L.	Yerkes 1938	14/10	Indolyl - butyric acid 3-5 mg. per 100 c.c. 20 hrs.	70	—	—	70	33	Cuttings taken earlier yielded similar results.
B. sempervirens var. *Handsworthii* Hort.	Yerkes 1938	14/10	Indolyl - butyric acid 3 mg. per 100 c.c. 20 hrs.	69	—	—	100	70	
Callicarpa purpurea Juss.	Yerkes 1938	16/7	Indolyl - butyric acid 3-10 mg. per 100 c.c. 20 hrs.	18	—	—	100	87	Easily rooted at different stages of growth.
Calycanthus occidentalis Hook. and Arn.	Warner and Went 1939	4/6	β - indolyl - acetic acid 100 mg. per litre 20 hrs.	32	Sand	10	0	0	Hardwood cuttings.
C. occidentalis Hook. and Arn.	Warner and Went 1939	4/6	β - indolyl - acetic acid 100 mg. per litre 20 hrs.	32	Sand	—	0	0	Softwood cuttings. Leaves fell.
Cananga odorata Hook f. and Thoms.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Caragana arborescens pendula Dippel	Scholz 1937	19/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	39	Sand/ Peat 1/1	—	66·7	66·7	
C. pygmaea DC.	Scholz 1937	27/7	Indolyl-acetic acid 20 mg. per litre 24 hrs.	32	Sand/ Peat 1/1	—	8·3	0	

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Cassine Maurocenia L.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Ceanothus cyaneus Eastwood	Warner and Went 1939	28/5	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	39	Sand	4	25	—	Hardwood cuttings.
C. cyaneus Eastwood	Warner and Went 1939	28/5	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	39	Sand	11	90	0	Softwood cuttings.
C. hybridus Hort. Marie Simon	Scholz 1937	29/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	100	60	
Celastrus scandens L.	Yerkes 1938	20/7	Indolyl - butyric acid 5 mg. per 100 c.c. 20 hrs.	34	—	—	90	0	Vines in active growth.
Cephalanthus occidentalis L.	Scholz 1937	28/7	Indolyl-acetic acid 20-200 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	100	100	
Chamaecyparis pisifera var. *plumosa* Beissn.	Yerkes 1938	20/10	Indolyl - butyric acid 3-8 mg. per 100 c.c. 20 hrs.	68	—	—	65	15	
Cherry (Malling rootstock $F\frac{2}{1}\frac{5}{1}1$)	Pearse 1939	30/6	Indolyl - butyric acid 15 p.p.m. 24 hrs.	28	Sand	10	90	50	Rooted best from shoots which had stopped growth.
Cherry (Malling rootstock $F\frac{2}{2}\frac{5}{1}1$)	Pearse 1939	30/6	Indolyl - butyric acid 15 p.p.m. 24 hrs.	28	Sand	10	100	90	Rooted best from shoots which had stopped growth.
Cherry (Malling rootstock $F\frac{2}{3}\frac{5}{1}1$)	Pearse 1939	30/6	Indolyl - butyric acid 15 p.p.m. 24 hrs.	28	Sand	10	90	40	Rooted best from shoots which had stopped growth.
Cherry (Malling rootstock $F\frac{1}{1}2$)	Pearse 1939	5/8	Indolyl - butyric acid 10 p.p.m. 24 hrs.	42	Sand	10	90	0	Rooted best from shoots which had stopped growth.

Chorizema varium Benth.	Hubert and Beke 1938	10/12	Indolyl-acetic acid 100 mg. per litre 22 hrs.	25	Sand	9	100	30	Great improvement in percentage rooting and number of roots per cutting.
Citrus sinensis Osbeck	Hubert and Beke 1938	11/1	Indolyl-acetic acid 100 mg. per litre 8 hrs.	18	Sand	—	100	60	More cuttings rooted after treatment.
Cladrastis lutea C. Koch.	Scholz 1937	15/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	100	100	
Cordyline stricta Endl.	Laibach 1937	—	Indolyl-acetic acid 0·06125% lanolin paste.	33	Sand	8	87·5	37·5	
Cornus alba L.	Laibach 1937	—	Indolyl-acetic acid 0·5% lanolin paste.	254	Sand	14	93	50	
C. Amomum Mill.	Yerkes 1938	13/7	Indolyl - butyric acid 3 mg. per 100 c.c. 20 hrs.	22	—	—	73	53	Taken when terminals were forming.
C. florida L.	Scholz 1937	20/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	37	Sand/ Peat 1/1	—	25	0	Rather more cuttings rooted when given a 12-hour day
C. florida var. *rubra* André	Yerkes 1938	13/7	Indolyl - butyric acid 5 mg. per 100 c.c. 4 hrs.	27	—	—	60	0	Best results from wood taken shortly before terminal buds had formed.
C. paniculata L'Hérit.	Yerkes 1938	30/7	Indolyl - butyric acid 8-10 mg. per 100 c.c. 4 hrs.	41	—	—	66	0	Best results from wood taken shortly before terminal buds had formed.
C. Purpusii Koehne	Laibach 1937	—	Indolyl-acetic acid 0·5% lanolin paste.	254	Sand	11	72·7	27·3	
Corylus Avellana atropurpurea Kirchn.	Scholz 1937	29/7	Indolyl-acetic acid 50 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	6·6	0	
C. Avellana var. *pendula* Goesch.	Scholz 1937	28/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	13·4	0	Cuttings given 12-hour day.

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Cotoneaster buxifolia Wallich	Laibach 1937	—	Indolyl-acetic acid						Treatment gave only very slight improvement in rooting.
C. microphylla Wallich	Yerkes 1938	13/10	Indolyl - butyric acid 8 mg. per 100 c.c. 4 hrs.	25	—	—	100	45	Nearly mature. July and August cuttings failed.
C. salicifolia Franch.	Lek and Krijthe 1937	October and November	Indolyl-acetic acid	—	Sand/ Peat 1/1	—	—	—	No positive results.
Crataegus Pyracantha Pers.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	No positive results.
Cunonia capensis L.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Cupressus Lawsoniana Murray	Hubert and Beke 1938	17/1	Indolyl-acetic acid 50 mg. per litre 8 hrs.	30	Sand	20	75	75	No improvement either in number of cuttings rooting or in quantity of roots per cutting.
Cydonia oblonga Mill. (Quince A)	Lek and Krijthe 1937	25/9	Indolyl-acetic acid 25γ 24 hrs.	35	Sand/ Peat 1/1	—	60	20	Results slightly positive.
(Quince B)		25/9	Indolyl-acetic acid	—	,,	—	—	—	,,
(Quince C)		25/9	Indolyl-acetic acid 25γ 24 hrs.	35	,,	—	80	20	,,
Cystisus Attleyanus Hort.	Scholz 1937	1/9	Indolyl-acetic acid 200 mg. per litre 24 hrs.	34	Sand/ Peat 1/1	—	90	10	
Daphne Laureola L.	Lek and Krijthe 1937	9/11	Indolyl-acetic acid 100γ 24 hrs.	84	Sand/ Peat 1/1	—	100	0	Some control cuttings rooted later.

Datura Cornucopia Hort.	Warner and Went 1939	8/4	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	13	Sand	5	100	40	
Davidia involucrata Baillon	Scholz 1937	15/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	33·3	0	
Deutzia corymbosa R. Brown	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Only slightly positive results obtained.
D. crenata Sieb. and Zucc.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Untreated cuttings superior.
D. gracilis Sieb. and Zucc.	Yerkes 1938	6/8	Indolyl - butyric acid 8-10 mg. per 100 c.c. 4 hrs.	17	—	—	90	79	Easily rooted at any time.
D. scabra Thunb. (—*D. crenata*) Sieb. and Zucc.	Tincker 1938	July	(1) Indolyl-acetic acid $\frac{1}{100}$ 24 hrs.	—	Sand	—	—	—	20% more cuttings rooted in 3 weeks.
			(2) α - Naphthalene-acetic acid $\frac{1}{1000}$ 24 hrs.	—	Sand	—	—	—	,,
Diervilla florida Sieb. and Zucc.	Tincker 1938	July	(1) Indolyl-acetic acid $\frac{1}{100}$ 24 hrs.	—	Sand	—	—	—	20% more cuttings rooted in 3 weeks.
			(2) α - Naphthalene-acetic acid $\frac{1}{100}$ 24 hrs.	—	Sand	—	—	—	,,
Elaeagnus pungens Thunb.	Yerkes 1938	11/10	Indolyl-butyric acid 3 mg. per 100 c.c. 4 hrs.	70	—	—	100	72	Earlier and later cuttings failed.
Elm (Evergreen)	Warner and Went 1939	20/6	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	23	Sand	15	100	0	
Enkianthus perulatus Schneid.	Skinner 1938	23/7	Indolyl - butyric acid 9 mg. per 100 c.c. 8 hrs.	35	Sand/ Peat 1/1	—	100	100	
Erica arborea, var. *alpina* Dieck	Tincker 1938	September	α-naphthalene-acetic acid $\frac{1}{100}$ 24 hrs.	—	Sand	—	—	—	50% more cuttings rooted in 2 weeks.
E. australis L.	Tincker 1938	September	,,	—	Sand	—	—	—	Little advantage by treatment.

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
E. caffra [? L.—ED.]	Tincker 1938	December	β - indolyl - acetic acid 1/1000 24 hrs.	—	Sand	—	—	—	Slight advantage from treatment.
E. darleyensis Bean	Skinner 1938	23/7	Indolyl - butyric acid 1 mg. per 100 c.c. 8 hrs.	28	Sand/ Peat 1/1	—	100	77	
E. melanthera L.	Tincker 1938	December	(1) β-indolyl-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	20% more cuttings rooted in 8 weeks.
			(2) α - naphthalene-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	72% more cuttings rooted in 8 weeks.
E. multicaulis Salisb.	Tincker 1938	September and October	(1) β-indolyl-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	Slight advantage from treatments.
			(2) α-naphthalene-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	,,
E. vagans L.	Tincker 1938	September	(1) β-indolyl-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	Treatments caused 20% more cuttings to root.
			(2) α-naphthalene-acetic acid 1/5000 for 24 hrs.	—	Sand	—	—	—	,,
E. Watsonii Jacks.	Tincker 1938	September	α - naphthalene-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	50% more cuttings rooted in 8 weeks.
Erinacea pungens Boiss.	Tincker 1938	December	Indolyl-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	No advantage from treatment.
Erythrina Corallodendron L.	Warner and Went 1939	4/5	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	21	Sand	5	100	0	

Escallonia langleyensis Veitch	Tincker 1938	July	(1) Indolyl-acetic acid $\frac{1}{1000}$ 24 hrs.	—	Sand	—	—	—	50% more cuttings rooted.
			(2) α-naphthalene-acetic acid $\frac{1}{1000}$ for 24 hrs.	—	Sand	—	—	—	,,
Eucalyptus globulus Labill.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Eucommia ulmoides Oliver	Tincker 1938	July	Indolyl-acetic acid $\frac{1}{1000}$ 24 hrs.	—	Sand	—	—	—	No positive results.
Euonymus patens Rehd.	Yerkes 1938	10/10	Indolyl - butyric acid 5 mg. per 100 c.c. 4 hrs.	14	—	—	91	40	Easily rooted. Similar results from cuttings made earlier.
E. radicans Sieb. and Zucc.	Laibach 1937	—	Indolyl-acetic acid 0·01% solution in water.	20	Sand	25	76	28	
Eriostemum sp.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Euphoria Litchi	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Eurya japonica Thunb.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Fagus sylvatica, var. *pendula* Lodd.	Scholz 1937	20/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	37	Sand/ Peat 1/1	—	50	0	
Feijoa Sellowiana Berg.	Tincker 1938	January	Indolyl-acetic acid $\frac{1}{1000}$ 24 hrs.	—	Sand	—	—	—	No rooting resulted.
Ficus australis Willd.	Hubert and Beke 1938	7/1	Indolyl-acetic acid 100 mg. per litre 8 hrs.	24	Sand	15	40	13	
F. Carica L. Calimyrna	Warner and Went 1939	17/3	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	34	Sand	5	100	80	

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
F. nitida Blume	Hubert and Beke 1938	21/12	Indolyl-acetic acid 100 mg. per litre 24 hrs.	14	Sand	8	90	0	Marked improvement in number rooting.
F. Porteana Regel	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	Very little effect.
F. cyatistipula Warb.	Hubert and Beke 1938	8/12	Indolyl-acetic acid 100 mg. per litre 22 hrs.	29	Sand	10	80	90	Treated cuttings had more roots. No gain in number rooting.
Forsythia intermedia Zabel	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Untreated cuttings rooted best.
F. intermedia Zabel	Oliver 1938	Mid June	Indolyl - butyric acid 40 p.p.m. 24hrs.	33	Sand	5	20	0	
		Late July	,,	45	Sand/ Peat	5	60	0	
F. suspensa Vahl	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treatment gave only slight improvement in rooting.
F. suspensa Vahl	Tincker 1938	June	(1) Indolyl - acetic acid $\frac{1}{1000}$ 24 hrs.	—	Sand	—	—	—	Accelerated root development by treatments.
			(2) α-naphthalene-acetic acid $\frac{1}{1000}$ for 24 hrs.	—	Sand	—	—	—	,,
Fothergilla alnifolia L. f.	Scholz 1937	15/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	100	100	
Fuchsia macrostemma Ruiz and Pav.	Tincker 1938	Septem-ber	(1) Indolyl - acetic acid $\frac{1}{4000}$ 24 hrs.	—	Sand	—	—	—	Treatments caused 80% more cuttings to root in 3 weeks.
			(2) α-naphthalene-acetic acid $\frac{1}{4000}$ for 24 hrs.	—	Sand	—	—	—	,,
			(3) Indolyl-butyric acid $\frac{1}{8000}$ 24 hrs.						

Galphimia brasiliensis A. Juss.	Hubert and Beke 1938	8/12	Indolyl-acetic acid 100 mg. per litre 22 hrs.	19	Sand	10	90	70	Many more roots per cutting after treatment.
Gardenia	Warner and Went 1939	26/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	27	Sand	32	100	0	
Gentiana sino-ornata Balf. f.	Hubert and Beke 1938	October	Indolyl-acetic acid $\frac{1}{10000}$ 24 hrs.	—	Sand	—	—	—	30% more cuttings rooted in 4 weeks.
Ginkgo biloba L.	Yerkes 1938	14/7	Indolyl - butyric acid 5 mg. per 100 c.c. 20 hrs.	36	—	—	90	80	Taken after terminals had formed.
Gordonia alatamaha Sarg.	Yerkes 1938	30/8	Indolyl - butyric acid 3 mg. per 100 c.c. 4 hrs.	29	—	—	83	34	Taken from young trees after terminal buds had formed.
Grevillea sulphurea A. Cunn.	Tincker 1938	October	Indolyl-acetic acid $\frac{1}{50000}$ 24 hrs.	—	Sand	—	—	—	10% more cuttings rooted.
Griselinia littoralis Raoul	Tincker 1938	May	Indolyl-acetic acid $\frac{1}{40000}$ 48 hrs	—	Sand	—	—	—	Slight advantage from treatment.
G. lucida Forst. f.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Gypsophila paniculata L.	Tincker 1938	July	Indolyl-acetic acid $\frac{1}{40000}$ 24 hrs.	—	Sand	—	—	—	Untreated and treated cuttings rooted 100% in 10 days.
Halesia tetraptera Ellis	Scholz 1937	17/7	Indolyl-acetic acid 100 mg. per litre 48 hrs.	40	Sand/ Peat 1/1	—	70	0	
Hamamelis virginiana L.	Scholz 1937	20/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	38	Sand/ Peat 1/1	—	33·3	0	

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Hedera Helix L.	Tincker 1938	January	(1) Indolyl-acetic acid $\frac{1}{10000}$ 24 hrs.	—	Sand	—	—	—	Both treatments caused 100% of cuttings to root in 4 weeks while untreated cuttings did not root.
			(2) α-naphthalene-acetic acid $\frac{1}{10000}$ 24 hrs.	—	Sand	—	—	—	,,
Hedysarum multijugum Maxim.	Scholz 1937	29/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	20	0	
Helichrysum rupestre DC. var. *helianthemifolium* (*Gnaphalium lanceolatum ?*)	Hubert and Beke 1938	3/12	Indolyl-acetic acid 100 mg. per litre 6 hrs.	13	Sand	20	90	40	More cuttings rooted. More roots per cutting.
Humulus Lupulus L. var. Brewer's Gold (Salmon 1934)	Bailey 1939	11/4	β - indolyl - acetic acid $\frac{1}{5000}$ 24 hrs.	—	Sand and Peat	10	100	50	
H. Lupulus L. var. Brewer's Gold (Salmon 1934)	Bailey 1939	11/4	Phenyl-acetic acid	—	Sand and Peat	10	80	50	
H. Lupulus L. var. Brewer's Gold (Salmon 1934)	Bailey 1939	20/6	β - indolyl - acetic acid $\frac{1}{10000}$ 24 hrs.	—	Sand and Peat	10	80	0	
H. Lupulus L. var. Brewer's Gold (Salmon 1934)	Bailey 1939	20/6	α - naphthalene-acetic acid $\frac{1}{20000}$ 24 hrs.	—	Sand and Peat	10	80	0	
Hydrangea hortensis	Warner and Went 1939	28/10	β - indolyl - acetic acid 200 mg. per litre 20 hrs.	17	Sand	6	66	0	

H. hortensis Smith =*H. opuloides* C. Koch	Tincker 1938	October	Indolyl-acetic acid 1/5000 24 hrs.	—	Sand	—	—	—	10% more cuttings rooted.
H. opuloides var. *otaksa* Dipp.	Scholz 1937	28/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	100	100	
H. paniculata Sieb.	Oliver 1938	Mid-June	Indolyl - butyric acid 20 p.p.m. 24 hrs.	30	Sand/ Peat 1/1	5	100	40	
H. quercifolia Bartr.	Scholz 1937	28/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	100	100	Cuttings planted directly only showed 33% rooting in a similar time.
H. Sargentiana Read	Scholz 1937	28/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	100	50	
H. scandens DC.	Scholz 1937	19/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	39	Sand/ Peat 1/1	—	60	60	Control cuttings planted directly.
Hymenaea Courbaril L.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement.
Hymenanthera crassifolia Hook f.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No positive results.
Ilex Aquifolium L.	Hubert and Beke 1938	7/1	Indolyl-acetic acid 100 mg. per litre 8 hrs.	32	Sand	20	75	0	Great improvement in number rooting.
I. cornata Lindl.	Yerkes 1938	22/6	Indolyl - butyric acid 3-8 mg. per 100 c.c. 4 hrs.	62	—	—	30	0	Soft wood best. No results from August cuttings.
I. crenata Thunb.	Yerkes 1938	22/6	Indolyl - butyric acid 8 mg. per 100 c.c. 4 hrs.	43	—	—	100	57	Cuttings from growing wood rooted soonest.
I. crenata Thunb.	Hitchcock and Zimmerman 1936	—	(1) Indolyl-butyric acid 2 mg. per 100 c.c. 24 hrs.	25	Sand/ Peat 1/1	—	100	—	Rooting accelerated and increased by treatment.
			(2) α-naphthalene-acetic acid 5 mg. per 100 c.c. 24 hrs.	25	Sand/ Peat 1/1	—	100	—	,,

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment*.	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
I. crenata var. *microphylla* Maxim.	Yerkes 1938	22/6	Indolyl - butyric acid 5 mg. per 100 c.c. 4 hrs.	62	—	—	87	20	Cuttings from growing wood rooted soonest.
I. glabra A. Gray	Yerkes 1938	29/7	Indolyl - butyric acid 5 mg. per 100 c.c. 4 hrs.	41	—	—	90	0	Half ripe wood.
I. opaca Ait.	Yerkes 1938	28/10	Indolyl - butyric acid 10 mg. per 100 c.c. 18 hrs.	23	—	—	96	0	Wood nearly mature.
I. opaca Ait.	Hitchcock and Zimmerman 1936	30/12	Indolyl-acetic acid 20 mg. per 100 c.c. 6 hrs.	35	Sand/ Peat 1/1	—	100	—	Controls showed some rooting later. Root formation increased and accelerated.
I. verticillata A. Gray	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treatment gave only slight improvement in rooting.
I. verticillata A. Gray	Lek and Krijthe 1937	October and November	Indolyl-acetic acid	—	—	—	—	—	No positive results.
Impatiens	Warner and Went 1939	10/1	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	18	Sand	8	100	0	
Iberis sempervirens L.	Laibach 1937	—	Indolyl-acetic acid 0·01% solution in water.	27	Sand	32	53·1	31·2	
Iresine Lindenii Van Houtte	Hubert and Beke 1938	3/12	Indolyl-acetic acid 50 mg. per litre 6 hrs.	10	Sand	14	100	100	Twice as many roots per cutting after treatment.
Ivy (variegated)	Warner and Went 1939	3/11	β - indolyl - acetic acid 100 mg. per litre 21 hrs.	19	Sand	10	90	40	

Jasminum sp.	Warner and Went 1939	17/3	β - indolyl - acetic acid 100 mg. per litre 24 hrs.	34	Sand	3	100	0	
J. Beesianum Diels and Forrest	Scholz 1937	29/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	100	50	
J. nudiflorum Lindl.	Scholz 1937	29/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	72·7	40	
J. nudiflorum Lindl.	Laibach 1937	—	Indolyl-acetic acid 0·5% lanolin paste	35	Sand	25	68	16	
J. primulinum Hemsl.	Scholz 1937	28/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	67	Sand/ Peat 1/1	-	100	40	
J. Stephanense Hort.	Scholz 1937	—	Indolyl-acetic acid		Sand/ Peat 1/1	—	—	—	No positive results.
J. Wallichianum Lindl.	Scholz 1937	28/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	100	80	Cuttings planted directly only gave 20% rooted.
Juniperus chinensis Pfitzeriana Späth	Lek and Krijthe 1937	—	Indolyl-acetic acid	—	—	—	—	—	A positive improvement obtained.
J. chinensis Pfitzeriana Späth	Yerkes 1938	18/10	Indolyl-butyric acid 5-8 mg. per 100 c.c. 20 hrs.	88	—	—	40	0	Similar results from earlier cuttings.
J. horizontalis var. *plumosa*	Yerkes 1938	20/10	Indolyl-butyric acid 5 mg. per 100 c.c. 20 hrs.	48	-	—	60	60	Results similar from August and September cuttings.
J. Sabina L.	Oliver 1938	Late July	Indolyl-butyric acid 100 p.p.m. 24 hrs.	52	Sand/ Peat 1/1	5	60	0	
Kalmia latifolia L.	Tincker 1938	March	Indolyl-acetic acid $\frac{1}{20000}$ 48 hrs.	—	Sand	—	—	—	Inconclusive results.
K. latifolia L. (leaves)	Skinner 1938	21/7	Indolyl-butyric acid 9 mg. per 100 c.c. 24 hrs.	133	Sand/ Peat 1/1	-	80	20	

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
K. latifolia L. (stems)	Skinner 1938	23/7	Indolyl-acetic acid 9 mg. per 100 c.c. 24 hrs.	126	Sand/ Peat 1/1	—	40	20	
K. latifolia var. *myrtifolia* Jäger	Tincker 1938	January	Indolyl-acetic acid $\frac{1}{10000}$ 48 hrs.	—	Sand	—	66	12	
Kerria japonica DC.	Tincker 1938	July	Indolyl-acetic acid $\frac{1}{30000}$ 24 hrs.	—	Sand	—	—	—	Root formation slightly accelerated.
Kleinia neriifolia Haw.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	Very little effect.
Kolkwitzia amabilis Graeb.	Yerkes 1938	2/7	Indolyl-butyric acid 6-10 mg. per 100 c.c. 4 hrs.	34	—	—	100	0	Taken before terminals had formed.
Laurus Camphora L.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	Very little effect.
L. nobilis L.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	Very little effect.
Lavandula vera DC.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.
Leucothoë Catesbaei (leaves) A. Gray	Skinner 1938	21/7	Indolyl-butyric acid 1 mg. per 100 c.c. 24 hrs.	49	Sand/ Peat 1/1	—	100	100	
L. Catesbaei (stems) A. Gray	Skinner 1938	21/7	Indolyl-butyric acid 1 mg. per 100 c.c. 24 hrs.	70	Sand/ Peat 1/1	—	100	100	
Ligustrum japonicum Thunb.	Yerkes 1938	21/6	Indolyl-butyric acid 3-5 mg. per 100 c.c. 20 hrs.	28	—	—	95	94	Growing tips rooted much sooner than older wood.

L. vulgare L. var. *atrovirens*	Laibach 1937	—	Indolyl-acetic acid 0·5% lanolin paste.	21	Water	60	58·3	0	
			Indolyl-acetic acid 0·5% lanolin paste.	20	Sand	60	20	5	Difference in response in sand and water.
Liriodendron tulipifera L.	Scholz 1937	15/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	33	0	
Lonicera yunnanensis Franch.	Tincker 1938	December	Indolyl-acetic acid $\frac{1}{2000}$ 24 hrs.	—	Sand	—	—	—	40% more cuttings rooted in 3 weeks.
		January	α-naphthalene-acetic acid $\frac{1}{2000}$ 24 hrs.	—	Sand	—	—	—	65% more cuttings rooted in 4 weeks.
Macadamia ternifolia F. Muell.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Maclura aurantiaca Nutt.	Scholz 1937	15/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	100	60	Cuttings planted directly gave 23% rooted.
Magnolia (Chinese)	Warner and Went 1939	1/5	β-indolyl-acetic acid 200 mg. per litre 24 hrs.	21	Sand	5	100	0	
M. denudata Desr.	Scholz 1937	15/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	41	Sand/ Peat 1/1	—	80	0	
M. hybrida var. *Norbertiana* Hort.	Scholz 1937	15/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	41	Sand/ Peat 1/1	—	100	11	Cuttings planted directly gave 37% rooted.
M. Kobus var. *borealis* Sarg.	Yerkes 1938	18/6	Indolyl-butyric acid 8-10 mg. per 100 c.c. 22 hrs.	24	—	—	58	0	In active growth when taken.
M. liliflora Desr.	Yerkes 1938	30/8	Indolyl-butyric acid 5 mg. per 100 c.c. 22 hrs.	49	—	—	100	21	Terminal buds were forming.
M. parviflora Sieb. and Zucc.	Scholz 1937	15/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	100	50	Cuttings planted directly gave 66·7% rooted.
M. Soulangiana Soul.	Scholz 1937	15/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	66·7	0	

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Malus Antonovka	Oliver 1938	Mid-June	Indolyl-butyric acid 10-100 p.p.m. 24 hrs.	—	—	—	—	—	All cuttings died.
M. Athabasca	Oliver 1938	Mid-June	Indolyl-butyric acid 10-100 p.p.m. 24 hrs.	—	—	—	—	—	All cuttings died.
M. Eleyi Hort.	Yerkes 1938	2/7	Indolyl-butyric acid 5 mg. per 100 c.c. 4 hrs.	34	—	—	70	0	Wood from young trees in active growth.
M. Erie	Oliver 1938	Mid-June	Indolyl-butyric acid 10-100 p.p.m. 24 hrs.	—	—	—	—	—	All cuttings died.
M. floribunda Kirchn.	Yerkes 1938	Late July	Indolyl-butyric acid 10-100 p.p.m. 24 hrs.	—	—	—	—	—	All cuttings died.
M. Hibernal	Yerkes 1938	Mid-June	Indolyl-butyric acid 10-100 p.p.m. 24 hrs.	—	—	—	—	—	All cuttings died.
M. Patten Greening	Yerkes 1938	Early August	Indolyl-butyric acid 10-100 p.p.m. 24 hrs.	—	—	—	—	—	No cuttings rooted.
Morus alba L.	Hubert and Beke 1938	11/1	Indolyl-acetic acid 100 mg. per litre 8 hrs.	12	Sand	—	100	66	Basal cuttings rooted better than apical. Treated cuttings showed pronounced bud inhibition.
M. alba L.	Warner and Went 1939	13/7	β-indolyl-acetic acid 100 and 200 mg. per litre 22 hrs.	30	Sand	6	0	0	Hardwood cuttings. Leaves fell.
M. alba L.	Warner and Went 1939	13/7	β-indolyl-acetic acid 100 mg. per litre 22 hrs.	30	Sand	17	76	47	Softwood cuttings.

M. nigra L.	Hubert and Beke 1938	24/1	Indolyl-acetic acid 100 mg. per litre 8 hrs.	25	Sand	—	62	12	
Myrica californica Cham.	Warner and Went 1939	4/6	β-indolyl-acetic acid 200 mg. per litre 20 hrs.	32	Sand	14	100	12	Softwood cuttings.
M. californica Cham.	Warner and Went 1939	4/6	β-indolyl-acetic acid 100 mg. per litre 20 hrs.	32	Sand	8	25	11	Hardwood cuttings.
M. Gale L.	Scholz 1937	20/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	38	Sand/ Peat 1/1	—	100	80	Cuttings planted directly rooted 60%
Myrtus pubescens	Hubert and Beke 1938	15/12	Indolyl-acetic acid 100 mg. per litre 22 hrs.	37	Sand	12	58	0	
M. Ugni Molina	Hubert and Beke 1938	8/12	Indolyl-acetic acid 100 mg. per litre 22 hrs.	33	Sand	12	58	16·5	More cuttings rooted.
Olearia Haastii Hook.	Lek and Krijthe 1937	11/11	Indolyl-acetic acid 25γ 28 hrs.	35	Sand/ Peat 1/1	—	80	30	
Osmanthus Aquifolium Sieb.	Yerkes 1938	29/7	Indolyl-butyric acid 15 mg. per 100 c.c. 4 hrs.	32	—	—	93	20	
O. Aquifolium Sieb.	Hubert and Beke 1938	15/12	Indolyl-acetic acid 100 mg. per litre 22 hrs.	41	Sand	12	100	55	More cuttings rooted. More roots per cutting.
Oxydendrum arboreum DC.	Skinner 1938	21/7	Indolyl-butyric acid 9 mg. per 100 c.c. 8 hrs.	56	Sand/ Peat 1/1	—	80	0	
Pachysandra terminalis Sieb.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings showed only slight improvement in rooting.
Parrotia persica C. A. Meyer	Scholz 1937	20/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	38	Sand/ Peat 1/1	—	100	50	
Pear (Malling Rootstock B.2)	Pearse 1939	28/7	Indolyl-butyric acid 20 p.p.m.	44	Sand	10	90	0	Shoots with growth stopped from established trees.

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Pear (Malling Rootstock C.2)	Pearse 1939	7/7	Indolyl-butyric acid 30 p.p.m. 24 hrs.	53	Sand	10	80	0	Shoots with growth stopped from established trees.
Pear (Malling Rootstock C.3)	Pearse 1939	28/7	Indolyl-butyric acid 40 p.p.m. 24 hrs.	44	Sand	10	60	0	Shoots with growth stopped from established trees.
Pear (Malling Rootstock C.4)	Pearse 1939	8/7	α-naphthalene-acetic acid 40 p.p.m 24 hrs.	54	Sand	10	80	0	Shoots with growth stopped from established trees.
Philadelphus coronarius L.	Laibach 1937	—	Indolyl-acetic acid 0·5% lanolin paste	254	Sand	64	51·5	25	
P. grandiflorus Willd.	Yerkes 1938	2/7	Indolyl-butyric acid 3-5 mg. per 100 c.c. 20 hrs.	33	—	—	75	70	Soft wood soon after flowering.
P. Norma	Yerkes 1938	2/7	Indolyl-butyric acid 3 mg. per 100 c.c. 4 hrs.	33	—	—	87	0	Soft wood soon after flowering.
P. Voie Lactée	Yerkes 1938	2/7	Indolyl-butyric acid 8 mg. per 100 c.c. 8 hrs.	33	—	—	42	10	Soft wood soon after flowering.
Photinia villosa DC.	Scholz 1937	28/7	Indolyl-acetic acid 50 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	10	0	
Physocarpus opulifolius Maxim.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.
Pieris floribunda Benth. and Hook.	Skinner 1938	1/7	Indolyl-butyric acid 1 mg. per 100 c.c. 8 hrs.	140	Sand/ Peat 1/1	—	20	0	
P. japonica (leaves) D. Don	Skinner 1938	21/7	Indolyl-butyric acid 9 mg. per 100 c.c. 8 hrs.	112	Sand/ Peat 1/1	—	90	60	

P. japonica (stems) D. Don	Skinner 1938	9/7	Indolyl-butyric acid 9 mg. per 100 c.c. 8 hrs.	42	Sand/ Peat 1/1	—	100	80	
Plum (Rootstock Brompton)	Pearse 1939	28/7	Indolyl-butyric acid 20 p.p.m. 24 hrs.	47	Sand	10	80	10	Non-growing shoots.
Plum (Rootstock Myrobolan B)	Pearse 1939	30/5	Indolyl-butyric acid 20 p.p.m. 24 hrs.	23	Sand	10	100	80	Non-growing shoots.
Plum (Rootstock Pershore)	Pearse 1939	28/7	Indolyl-butyric acid 20 p.p.m. 24 hrs.	47	Sand	10	30	0	Non-growing shoots.
Plum (Scion variety Victoria)	Pearse 1939	6/7	α-naphthalene-acetic acid 15 p.p.m. 24 hrs.	50	Sand	10	80	0	Non-growing shoots.
Poncirus trifoliata Raf.	Gočolašvili and Maximov 1937	December	β-indolyl-acetic acid $\frac{1}{3000}$ 24 hrs.	30	Sand/ Peat 1/1	—	100	0	Cuttings which had not shed their leaves rooted most rapidly.
Populus alba var. *Bolleana* Lauche	Laibach 1937	—	Indolyl-acetic acid 0·5% lanolin paste.	170	Sand	48	41·6	18·7	
P. alba var. *pyramidalis* Bunge	Laibach 1937	26/8	Indolyl-acetic acid 0·01% solution in water 24 hrs.	19	Sand	25	56	20	
Potentilla fruticosa L.	Laibach 1937	26/8	Indolyl-acetic acid 0·01% solution 24 hrs.	9	Sand	24	50	0	
Prunus cerasifera Ehrh. (1) Myrobolan A	Lek and Krijthe 1937	2/7	Indolyl-acetic acid 25γ 24 hrs.	28	Sand/ Peat 1/1	—	—	—	Percentage of cuttings rooting increased. Type A more sensitive than Type B.
(2) Myrobolan B		2/7	,,	11	Sand/ Peat 1/1	—	—	—	
P. triloba plena Hort.	Yerkes 1938	15/7	Indolyl-butyric acid 5-10 mg. per 100 c.c. 4 hrs.	21	—	—	33	0	Terminal buds had formed.
Pterocarya stenoptera DC.	Scholz 1937	27/7	Indolyl-acetic acid 20 mg. per litre 24 hrs.	69	Sand/ Peat 1/1	—	33·3	0	

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
Pterostyrax hispidum Sieb. and Zucc.	Scholz 1937	28/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	46·7	9·1	
Pyracantha coccinea Roem.	Yerkes 1938	14/10	Indolyl - butyric acid 3 mg. per 100 c.c. 4 hrs.	70	—	—	81	45	Nearly mature. July and August cuttings failed.
P. crenulata Roem.	Lek and Krijthe 1937	11/9	Indolyl-acetic acid 50γ 20 hrs.	35	Sand/ Peat 1/1	—	100	0	
Quercus Suber L.	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Rhododendron catawbiense Pursh (leaves)	Skinner 1938	23/7	Indolyl-butyric acid 8 mg. per 100 c.c. 24 hrs.	126	Sand/ Peat 1/1	—	100	90	
R. catawbiense Pursh (stems)	Skinner 1938	9/8	Indolyl-butyric acid 1 mg. per 100 c.c. 8 hrs.	84	Sand/ Peat 1/1	—	100	80	
R. dahuricum sempervirens Sims	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	147	Sand/ Peat 1/1	—	80	80	
R. dahuricum var. *sempervirens* Sims	Scholz 1937	28/7	Indolyl-acetic acid 50 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	33·3	0	Given 12 hr. day.
R. decorum Franch. (leaves)	Skinner 1938	26/7	Indolyl-butyric acid 8 mg. per 100 c.c. 24 hrs.	63	Sand/ Peat 1/1	—	100	20	
R. altaclerense var. *Veitchii* Hort.	Skinner 1938	27/6	Indolyl-butyric acid.	—	Sand/ Peat 1/1	—	0	0	
R. gandavense var. Bouquet de Flore	Skinner 1938	26/6	Indolyl-butyric acid 1 mg. per 100 c.c. 10 hrs.	91	Sand/ Peat 1/1	—	80	80	

R. gandavense Domenico Scassi	Skinner 1938	26/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	126	Sand/ Peat 1/1	—	60	40	
R. gandavense Gloria Mundi	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	140	Sand/ Peat 1/1	—	71	57	
R. gandavense Grandeur Triomphant	Skinner 1938	26/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	105	Sand/ Peat 1/1	—	100	0	
R. gandavense Pucelle	Skinner 1938	26/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	126	Sand/ Peat 1/1	—	100	60	
R. gandavense Reine Louise	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	126	Sand/ Peat 1/1	—	83	60	
R. gandavense Rosetta	Skinner 1938	26/6	Indolyl-butyric acid 1 mg. per 100 c.c. 10 hrs.	105	Sand/ Peat 1/1	—	100	80	
R. gandavense Ruddy Ghent	Skinner 1938	27/6	Indolyl-butyric acid 1 mg. per 100 c.c. 10 hrs.	147	Sand/ Peat 1/1	—	17	50	
R. gandavense Souvenir de President Carnot	Skinner 1938	30/6	Indolyl-butyric acid 1 mg. per 100 c.c. 10 hrs.	140	Sand/ Peat 1/1	—	17	50	
R. gandavense Unique	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	154	Sand/ Peat 1/1	—	50	20	
R. japonicum [Schneid. or Suring ?—Ed.]	Skinner 1938	30/6	Indolyl-butyric acid 1 mg. per 100 c.c. 24 hrs.	77	Sand/ Peat 1/1	—	90	60	
R. japonicum aureum	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	63	Sand/ Peat 1/1	—	100	100	Rooting accelerated and more roots per cutting.
R. Kaempferi Planch. [=Azalea Kaempferi, which see.—Ed.]	Skinner 1938	6/8	Indolyl-butyric acid 9 mg. per 100 c.c. 8 hrs.	28	Sand/ Peat 1/1	—	100	100	Rooting accelerated and more roots per cutting.
R. maximum L. (leaves)	Skinner 1938	21/7	Indolyl-butyric acid 9 mg. per 100 c.c. 24 hrs.	91	Sand/ Peat 1/1	—	100	20	

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
R. micranthum Turcz.	Skinner 1938	21/7	Indolyl-butyric acid 1 mg. per 100 c.c. 8 hrs.	91	Sand/ Peat 1/1	—	100	60	
R. minus Michx. (leaves)	Skinner 1938	1/7	Indolyl-butyric acid 9 mg. per 100 c.c. 24 hrs.	112	Sand/ Peat 1/1	—	90	100	Rooting accelerated by treatment.
R. minus Michx. (stems)	Skinner 1938	8/7	Indolyl-butyric acid 9 mg. per 100 c.c. 8 hrs.	98	Sand/ Peat 1/1	—	40	20	
R. mixtum (hybs. of *R. rustica*) Apelles	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	154	Sand/ Peat 1/1	—	80	0	
R. mixtum Il Tasso	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	140	Sand/ Peat 1/1	—	100	20	
R. mixtum Phoebe	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	140	Sand/ Peat 1/1	—	60	20	
R. molle var. *albicans*	Skinner 1938	26/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	70	Sand/ Peat 1/1	—	100	0	
R. molle Compte de Gomer	Skinner 1938	26/6	Indolyl-butyric acid.	—	Sand/ Peat 1/1	—	0	0	No effective treatment.
R. molle Elizabeth	Skinner 1938	26/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	70	Sand/ Peat 1/1	—	40	25	
R. molle Frère Orban	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	70	Sand/ Peat 1/1	—	100	20	
R. molle General Brailmont	Skinner 1938	26/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	56	Sand/ Peat 1/1	–	100	100	More roots per cutting.

R. molle Mignon	Skinner 1938	27/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	63	Sand/ Peat 1/1	—	100	100	Rooting accelerated.
R. ledifolium Don	Skinner 1938	21/7	Indolyl-butyric acid 1 mg. per 100 c.c. 24 hrs.	35	Sand/ Peat 1/1	—	100	90	
R. ponticum L.	Skinner 1938	26/7	Indolyl-butyric acid 4 mg. per 100 c.c. 24 hrs.	63	Sand/ Peat 1/1	—	80	80	More roots per cutting.
R. ponticum L. (leaves)	Skinner 1938	26/7	Indolyl-butyric acid 4 mg. per 100 c.c. 8 hrs.	56	Sand/ Peat 1/1	—	100	80	
R. pulchrum var. *Maxwellii*	Skinner 1938	21/7	Indolyl-butyric acid 9 mg. per 100 c.c. 24 hrs.	35	Sand/ Peat 1/1	—	100	100	More roots per cutting.
R. racemosum Franch.	Skinner 1938	26/7	Indolyl-butyric acid 9 mg. per 100 c.c. 24 hrs.	77	Sand/ Peat 1/1	—	100	100	More roots per cutting.
R. reticulatum D. Don	Skinner 1938	26/7	Indolyl-butyric acid 4 mg. per 100 c.c. 8 hrs.	35	Sand/ Peat 1/1		100	100	More roots per cutting.
R. roseum Hort.	Skinner 1938	26/7	Indolyl-butyric acid 8 mg. per 100 c.c. 8 hrs.	112	Sand/ Peat 1/1	—	40	0	
R. Vaseyi A. Gray	Skinner 1938	30/6	Indolyl-butyric acid 1 mg. per 100 c.c. 8 hrs.	105	Sand/ Peat 1/1	—	60	30	
R. viscosepalum var. *Daviesii* Rehd.	Skinner 1938	26/6	Indolyl-butyric acid 9 mg. per 100 c.c. 10 hrs.	70	Sand/ Peat 1/1	—	100	80	
R. viscosum Torr.	Skinner 1938	21/7	Indolyl-butyric acid 9 mg. per 100 c.c. 24 hrs.	28	Sand/ Peat 1/1	—	100	100	More roots per cutting.
Rosa Dizzy Bee	Warner and Went 1939	11/1	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	20	Sand	5	100	0	
R. Ecae Aitch.	Scholz 1937	28/7	Indolyl-acetic acid 20 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	66·7	25	

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
R. Ellen Poulsen	Oliver 1938	Mid-June	Indolyl-butyric acid 40 p.p.m. 24 hrs.	36	Sand/ Peat 1/1	5	40	0	
R. odorata Sweet (Tea Rose)	Yerkes 1938	18/6	Indolyl-butyric acid 3-10 mg. per 100 c.c. 18 hrs.	12	—	—	95	89	Easily rooted at any time.
R. sericea var. *pteracantha* Franch.	Scholz 1937	28/7	Indolyl-acetic acid 20 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	27·3	0	
R. sp.	Oliver 1938	Mid-June	Indolyl-butyric acid 20 p.p.m. 24 hrs.	36	Sand/ Peat 1/1	5	20	0	
R. sp.	Warner and Went 1939	21/9	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	19	Sand	8	75	10	
Salvia apiana	Warner and Went 1939	9/3	β - indolyl - acetic acid 200 mg. per litre 36 hrs.	23	Sand	5	100	0	
S. mellifera Greene	Warner and Went 1939	15/2	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	17	Sand	5	100	0	
S. mellifera Greene	Warner and Went 1939	11/3	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	23	Sand	5	100	63	
Sansevieria guineensis Willd.	Laibach 1937	8/11	Indolyl-acetic acid 0·5% lanolin paste	41	Sand	25	76	12	
Senecio Greyii Hook. f.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.
Skimmia sp.	Hubert and Beke 1938	26/11	Indolyl-acetic acid 100 mg. per litre 8 hrs.	24	Sand	10	90	30	More cuttings rooted. More roots per cutting.

Spiraea prunifolia Sieb. and Zucc.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.
S. Thunbergii Sieb. and Zucc.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.
Stewartia Pseudo-camellia Maxim.	Scholz 1937	15/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	41	Sand/ Peat 1/1	—	50	33·3	
Styrax japonica Sieb. and Zucc.	Yerkes 1938	16/7	Indolyl-butyric acid 5 mg. per 100 c.c. 4 hrs.	23	-	—	100	10	Terminal buds were forming.
Symplocos crataegoides Buch.-Ham.	Scholz 1937	27/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	16·7	0	
Syringa chinensis Willd.	Laibach 1937	—	Indolyl-acetic acid 0·125% lanolin paste	78	Sand	40	15	0	
S. formosissima Nakai	Scholz 1937	24/7	Indolyl-acetic acid 50 mg. per litre 48 hrs.	71	Sand/ Peat 1/1	—	33·3	0	
S. Prestoniae Celia	Oliver 1938	Mid-June	Indolyl-butyric acid 80 p.p.m. 24 hrs.	43	Sand/ Peat 1/1	5	40	0	
S. Prestoniae Miranda	Oliver 1938	Late July	Indolyl-butyric acid 40 p.p.m. 24 hrs.	46	Sand/ Peat 1/1	5	60	20	
S. Prestoniae Virgilia	Oliver 1938	Mid-June	Indolyl-butyric acid 40 p.p.m. 24 hrs.	43	Sand/ Peat 1/1	5	20	0	
S. Prestoniae Calphurnia	Oliver 1938	Mid-June	Indolyl-butyric acid 80 p.p.m. 24 hrs.	43	Sand	5	80	20	
S. Prestoniae Jessica	Oliver 1938	Mid-June	Indolyl-butyric acid 80 p.p.m. 24 hrs.	43	Sand	5	20	0	

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks
							Treated.	Control.	
S. Prestoniae Charmiam	Scholz 1937	23/7	Indolyl-acetic acid 50 mg. per litre 24 hrs.	35	Sand/ Peat 1/1	—	87·5	16·7	
S. vulgaris L.	Warner and Went 1939	15/3	β - indolyl - acetic acid 200 mg. per litre 23 hrs.	21	Sand	9	33	—	Hardwood cuttings.
S. vulgaris L.	Warner and and Went 1939	15/3	β - indolyl - acetic acid 200 mg. per litre 23 hrs.	21	Sand	18	88	10	Softwood cuttings.
S. vulgaris L. Belle de Nancy	Scholz 1937	23/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	35	Sand/ Peat 1/1	—	42·9	16·7	
S. vulgaris L. Charles Joly	Scholz 1937	24/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	72	Sand/ Peat 1/1	—	80	0	Cuttings planted directly gave 40% rooted.
S. vulgaris L. Condorcet	Scholz 1937	23/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	72	Sand/ Peat 1/1	—	75	20	
S. vulgaris L. hybrids	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.
S. vulgaris L. Louvois	Yerkes 1938	18/5	Indolyl-butyric acid 5 mg. per 100 c.c.	61	—	—	49	41	Soft wood soon after flowering. No results from harder wood.
S. vulgaris L. Maureen	Oliver 1938	Mid-June	Indolyl-butyric acid 80 p.p.m. 24 hrs.	44	Sand/ Peat 1/1	5	40	0	
S. vulgaris L. Muriel	Oliver 1938	Mid-June	Indolyl-butyric acid 80 p.p.m. 24 hrs.	45	Sand/ Peat 1/1	5	20	0	

S. vulgaris L. Mme. Casimir Perier	Scholz 1937	26/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	70	Sand/ Peat 1/1	—	25·9	0	
S. vulgaris L. Mme. Lemoine	Scholz 1937	23/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	35	Sand/ Peat 1/1	—	42·9	0	Cuttings planted directly gave 20% rooted.
S. vulgaris L. Peggy	Yerkes 1938	Mid-June	Indolyl-butyric acid 80 p.p.m. 24 hrs.	45	Sand	5	40	0	
S. vulgaris L. Président Grévy	Scholz 1937	23/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	72	Sand/ Peat 1/1	—	80	40	Cuttings planted directly gave 20% rooted.
S. vulgaris L. Thunberg.	Oliver 1938	Mid-June	Indolyl-butyric acid 80 p.p.m. 24 hrs.	45	Sand/ Peat 1/1	5	40	0	
S. vulgaris L. Thunberg.	Oliver 1938	Late July	Indolyl-butyric acid 20 p.p.m. 24 hrs.	46	Sand/ Peat 1/1	5	60	20	
Tamarix gallica L.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.
Taxus cuspidata Sieb. and Zucc.	Yerkes 1938	31/12	Indolyl-butyric acid 5-8 mg. per 100 c.c. 22 hrs.	56	—	—	95	30	Short laterals. Winter cuttings rooted sooner than those taken in July, Aug., Oct. and Nov.
Taxus cuspidata Sieb. and Zucc.	Oliver 1938	Late July	Indolyl-butyric acid 80 p.p.m. 24 hrs.	53	Sand/ Peat 1/1	5	60	0	
Taxus cuspidata Sieb. and Zucc.	Hitchcock and Zimmerman 1936	—	α-naphthalene-acetic acid 4 mg. per 100 c.c. for 24 hrs.	63	Sand/ Peat 1/1	—	80	0	
Tecoma radicans Juss.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Treated cuttings rooted only slightly better than untreated.

INDEX OF SOME TYPICAL RESULTS OBTAINED WITH VARIOUS SPECIES—*continued.*

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
T. radicans Juss.	Scholz 1937	29/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	100	100	
Thuja occidentalis L.	Oliver 1938	Late July	Indolyl-butyric acid 40 p.p.m. 24 hrs.	43	Sand/ Peat 1/1	5	40	0	
T. occidentalis var. *globosa* Hort.	Yerkes 1938	20/10	Indolyl-butyric acid 6-8 mg. per 100 c.c. 20 hrs.	69	—	—	85	25	
T. occidentalis var. *pyramidalis* Endl.	Oliver 1938	Mid-June	Indolyl-butyric acid 100 p.p.m. 24 hrs.	53	Sand/ Peat 1/1	5	80	0	
T. occidentalis var. *Wareana* Beiss.	Oliver 1938	Mid-June	Indolyl-butyric acid 100 p.p.m. 24 hrs.	52	Sand/ Peat 1/1	5	80	0	
T. plicata D. Don	Yerkes 1938	13/1	Indolyl-butyric acid 8-10 mg. per 100 c.c. 22 hrs.	62	—	—	79	0	
Tsuga canadensis Carr.	Yerkes 1938	13/1	Indolyl-butyric acid 5-10 mg. per 100 c.c. 22 hrs.	62	—	—	79	0	No results from cuttings made in summer and autumn.
T. heterophylla Sarg.	Lek and Krijthe	13/1	Indolyl-acetic acid	—	—	—	—	—	Positive results obtained.
Vaccinium corymbosum L'Hérit.	Scholz 1937	17/7	Indolyl-acetic acid 100 mg. per litre 48 hrs.	40	Sand/ Peat 1/1	—	50	0	
Vangueria edulis Vahl	Hubert and Beke 1938	—	Indolyl-acetic acid 100 mg. per litre 22 hrs.	—	Sand	—	—	—	No improvement in rooting.
Viburnum Carlesii Hemsl.	Scholz 1937	10/7	Indolyl-acetic acid 50 mg. per litre 48 hrs.	46	Sand/ Peat 1/1	—	91·0	20	

V. cassinoides L.	Yerkes 1938	23/6	Indolyl-butyric acid 3-5 mg. per 100 c.c. 4 hrs.	26	—	—	30	30	
V. dentatum L.	Yerkes 1938	23/6	Indolyl-butyric acid 3-5 mg. per 100 c.c. 4 hrs.	44	—	—	100	80	Rooted best from wood taken while growth was still active.
V. dilatatum Thunb.	Yerkes 1938	19/6	Indolyl-butyric acid 3-10 mg. per 100 c.c. 2 hrs.	31	—	—	100	70	Rooted best from wood taken while growth was still active.
V. Lantana L.	Laibach 1937	—	Indolyl-acetic acid	—	—	—	—	—	Untreated cuttings rooted better than treated.
V. Lantana L.	Oliver 1938	Late July	Indolyl-butyric acid 40 p.p.m. 24 hrs.	45	Sand/ Peat 1/1	5	20	0	
V. Lantana L.	Yerkes 1938	23/6	Indolyl-butyric acid 5 mg. per 100 c.c. 4 hrs.	26	—	—	66	58	
V. plicatum Miq.	Yerkes 1938	20/7	Indolyl-butyric acid 3-5 mg. per 100 c.c. 20 hrs.	—	—	—	33	0	
V. Sieboldii Miq.	Yerkes 1938	23/6	Indolyl-butyric acid 3-5 mg. per 100 c.c. 4 hrs.	26	—	—	92	0	
V. Tinus L.	Hubert and Beke 1938	3/12	Indolyl-acetic acid 50 mg. per litre 6 hrs.	17	Sand	10	100	30	A fortnight later all the cuttings had rooted. Rooting accelerated and number of roots per cutting increased.
V. Tinus fol. var. Ait.	Hubert and Beke 1938	21/12	Indolyl-acetic acid 50 mg. per litre 24 hrs.	21	Sand	10	100	80	More cuttings rooted and more roots per cutting.

Name.	Workers.	Date cuttings taken.	Treatment.*	Rooting time in days.	Rooting medium.	Number of cuttings.†	Percentage rooted.		Remarks.
							Treated.	Control.	
V. tomentosum Thunb.	Yerkes 1938	23/6	Indolyl-butyric acid 3-5 mg. per 100 c.c. 4 hrs.	26	—	—	91	92	
V. tomentosum Thunb.	Scholz 1937	26/7	Indolyl-acetic acid 50 mg. per litre 24 hrs.	32	Sand/ Peat 1/1	—	100	100	
V. Wrightii Miq.	Yerkes 1938	23/6	Indolyl-butyric acid 3-10 mg. per 100 c.c. 4 hrs.	26	—	—	100	59	
Vitex Agnus-castus L.	Scholz 1937	15/7	Indolyl-acetic acid 100 mg. per litre 24 hrs.	42	Sand/ Peat 1/1	—	100	0	
Vitus Agnus-castus L.	Hubert and Beke 1938	15/12	Indolyl-acetic acid 100 mg. per litre 22 hrs.	20	Sand	—	92	76	Basal cuttings rooted better than apical.
Vitis rotundifolia Michx.	Yerkes 1938	16/8	Indolyl-butyric acid 2 mg. per 100 c.c. 20 hrs.	22	—	—	44	0	Best rooting from third to sixth nodes back from growing tips.
V. vinifera L. Concord	Warner and Went 1939	17/3	β - indolyl - acetic acid 100 mg. per litre 24 hrs.	34	Sand	10	100	100	More roots per cutting.
V. vinifera Empress	Warner and Went 1939	17/3	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	34	Sand	10	100	100	More roots per cutting.
V. vinifera Thompson	Warner and Went 1939	17/3	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	26	Sand	10	100	70	More roots per cutting.
Weigela rosea Lindl. =*Diervilla florida* Sieb. and Zucc.	Laibach 1937	—	Indolyl-acetic acid 0·01% solution in water.	28	Sand	20	55	20	

Wisteria sinensis Sweet	Lek and Krijthe 1937	1/7	Indolyl-acetic acid 100γ 12 hrs.	28	Sand/ Peat 1/1	—	100	0	
W. sinensis albiflora Lemaire	Scholz 1937	29/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	65	Sand/ Peat 1/1	—	70	9·1	
W. sinensis Sieb. and Zucc.	Scholz 1937	29/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	30	Sand/ Peat 1/1	—	100	44·4	Cuttings planted directly rooted 60%
Wisteria sinensis (white)	Warner and Went 1939	1/5	β - indolyl - acetic acid 200 mg. per litre 24 hrs.	21	Sand	5	100	0	
Zelkova serrata Makino	Scholz 1937	27/7	Indolyl-acetic acid 200 mg. per litre 24 hrs.	31	Sand/ Peat 1/1	—	90·9	0	

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Additional references on the propagation of conifers have
n brought to Dr. Pearse's notice by the Imperial Forestry
eau as follows:-

Grace, N.H. (1939). The vegetative propagation of conifers. I. Rooting of cuttings taken from the upper and lower region of a Norway spruce tree. Canad.J.Res., 17, Section C, pp.178-80.

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Also on the propagation of other forest tree species,
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